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Nitrates and the Ordnance Department

ARMY ORDNANCE

VOL. IV WASHINGTON, D. C., NOVEMBER-DECEMBER, 1923 No. 21

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The Muscle Shoals Situation—Ordnance Progress

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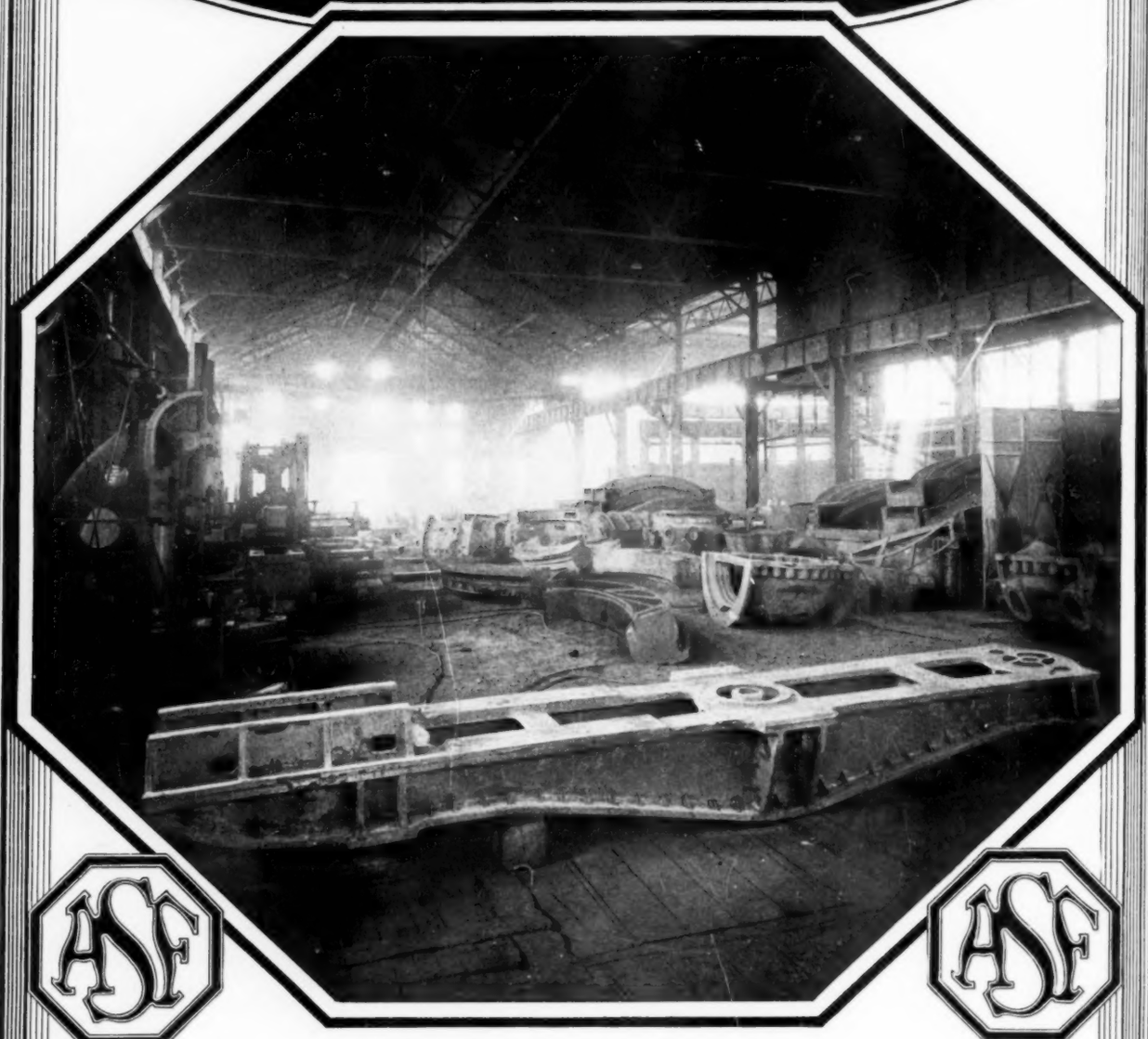

STEEL CASTINGS OF EVERY DESCRIPTION
FOR
ARMY AND NAVY REQUIREMENTS

ARMY ORDNANCE

THE JOURNAL OF THE ARMY ORDNANCE ASSOCIATION

Pledged to Public Service in Effecting Industrial Preparedness for War as Our Strongest Guarantee of Peace

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Judge Elbert H. Gary, President, the American Iron and Steel Institute, and Major General C. C. Williams, Chief of Ordnance, U. S. A., at the Fifth Annual Meeting of the Army Ordnance Association, Aberdeen Proving Ground, October 26, 1923

"AND may I add, though perhaps it may seem unnecessary, should in the future our beloved Country again be thrust into the necessity for national defense, that the iron and steel industry will again promptly and with vigor meet the situation to the utmost of its ability. We have in the United States a total capacity for steel production greater than that of any other country, greater, indeed, than the combined capacities of all the other countries, and I wish you gentlemen of the Army to know that in your studies of preparedness for national safety that the iron and steel men are behind you with their sympathies, abilities and resources. I congratulate you again, General Williams, and your associates, and you gentlemen of the Army Ordnance Association, on the great and valuable work you are engaged in, as so interestingly and capably displayed here today. And I wish again to thank you for the opportunity given us to see, at least in a measure, the results of your efforts, and to assure you once more of the sincere cooperation of the iron and steel men of this great Country of ours, both as individuals and through the American Iron and Steel Institute."

(From the address of Judge Gary at the joint meeting of the American Iron and Steel Institute and the Army Ordnance Association, Aberdeen Proving Ground, October 26, 1923.)

Editorials

The Meeting

THE Fifth Annual Meeting at Aberdeen, October 26th, was a great success. There was more interest shown both by the invited guests and by the members of the Association than at any other of the recent meetings; the large number who attended was most gratifying; the lengthy program of demonstrations and exhibits was most successfully carried out—thanks to the Commanding Officer at the Proving Ground and his staff of assistants—and the entire day was an interesting and enjoyable affair. That this is so, is based upon the unqualified and practically unanimous opinion of those who attended.

Possibly a few random thoughts inspired by the meeting may not be amiss here. They may only be the afterthought that is in the minds of all who attended, but at least by recording them here we will be putting them where those who pass by the road may see.

First, it was a real pleasure to have with us the members of the American Iron and Steel Institute. Their presence in such large numbers seemed to indicate that our pleasure in having them was equalled by their delight in being there. This, in itself, would have been ample recompense for the joint meeting. Secondly, the gathering resolved itself into one of the most significant demonstrations and assurances of adequate national preparedness that have been held in peace times in our Country.

We have printed on the opposite page an excerpt from the address of Judge Gary at Aberdeen. Its meaning and import to the cause of industrial preparedness are almost beyond measure. *"Should in the future our beloved Country be thrust into the necessity for national defense the iron and steel industry will again promptly and with vigor meet the situation to the utmost of its ability."* As the Judge added, such a statement might seem unnecessary. The record of the steel and iron industry during the World War proves it so. But coming as it did as a climax of a most unusual demonstration, and as a guarantee that industry, as typified by the Institute, will always be ready to put in effect the plans of Ordnance whenever the needs of defense demand, the import of the statement, we repeat, is almost beyond measure.

That our meeting should have resulted in such a remarkable approbation of our cause is no small accomplishment. We should all feel happy that the aims and objects of the Army Ordnance Association are becoming assimilated and understood by the citizens of our land. And we can point with pride that this, our fifth annual meeting, has probably accomplished more than any other one step that has been taken by any organization of private individuals toward the ultimate realization of adequate industrial preparedness. It is to be hoped that the good work will increase in effectiveness as the years go by.

The Report of the Chief of Ordnance

UNDER the title of Ordnance Progress there are printed elsewhere in this issue extracts from the annual report of the Chief of Ordnance, Major General C. C. Williams, to the Secretary of War for the fiscal year ended June 30, 1923. These extracts were recently made public by the War Department. They indicate the satisfactory progress which the Ordnance Department has made with the funds available and the need of more liberal appropriations in the future if the United States is to keep its ordnance development and its reserves on a parity with other powers of the first class.

Broadly speaking, the Ordnance Department has two major peace-time functions which bear upon war preparedness from the standpoint of matériel. The first of these is development—to insure that our fighting material shall be at least as up-to-date and efficient as that available for use by any possible enemy. The second is the maintenance of a war reserve of guns, ammunition, and other equipment to meet the needs of our forces in combat and in training from the onset of war until industry is able to take on the load and furnish the necessary supplies from current production.

Development in ordnance is a continuous process, exactly as it is in the automobile industry, the radio industry, and every other industry known to man. A nation can keep its fighting equipment up-to-date and efficient in comparison with that of other nations in the same way, and only in the same way that an automobile company, for instance, keeps itself abreast of its competitors—by the maintenance of a staff of engineers and scientists whose business it is continuously to develop new designs and advance the state of the art. For our Army, this duty devolves on the Ordnance Department, and General Williams' report shows clearly that, while we are making excellent progress in development, this progress would be materially accelerated if additional funds were available.

With respect to reserves, General Williams' report also shows that additional funds are required if we are to maintain a degree of preparedness deemed essential by those who have studied the problem. While we are fortunate in having left over from the World War vast quantities of ammunition and other war material, the ammunition, at least, has but a limited life and it will shortly become necessary to begin to replace our deteriorating stores by new manufacture.

The degree of preparedness to be reached and maintained in this Country will be determined by the American people. Whatever studies are made and conclusions arrived at by the War Department can be rendered effective only to the extent that they appear reasonable to the body politic and secure the essential support of appropriations. This is as it should be. We bespeak the careful attention of our readers for General Williams' report to the end that that portion of the American public which they represent may be informed of the conditions which exist.

Membership

DOUBTLESS by this time all the members of the Association have received notice acquainting them with the drive for increased membership that is now on.

A roster of all members as of November 12, arranged geographically, has been sent out, accompanied by descriptive folders and application blanks for distribution to prospective members. It is hoped that everyone will be successful in bringing in at least two new members.

At the business meeting of the Association at Aberdeen, October 26th, it was decided to start this campaign at once. All present took to the suggestion most enthusiastically.

It should not be difficult for each one of us to enroll a few new members. Each of us has some friends who are ideal candidates. The sole qualification is the desire and interest to help the cause of adequate industrial preparedness.

Much interest has been displayed in recent months in the several local posts of the Association. The New York Post is doing excellent work, and the proposed posts in Philadelphia and San Francisco have every augury for their ultimate success. Local activity will thus have a very decided impetus and the general aims and objects of the organization will be enhanced all the more.

Safeguarding the blessings of peace by preventing the wastes of war is a mission worthy of the sanction and support of every one claiming the name American. "Selling" such a proposition should entail little need for persuasion, much less for argument. It has much the appearance of a national life insurance policy—a protection against the uncertainty and perils of the future. Surely such an objective should meet with the active support of all.

The Association expects every man to do his duty! On our strength depends our effectiveness. Let us see to it that this work so auspiciously started and so successfully carried on during the past five years may grow in followers and friends and by its membership indicate the loftiness of its cause.

Who's Who in this Issue

THIS issue of ARMY ORDNANCE is devoted for the most part to nitrogen fixation. Nitrate is an Ordnance responsibility and so much publicity has been given the subject recently that a general discussion of the many phases of the subject may not be amiss at this time.

GENERAL JOHN W. JOYES, who contributes the article on "Nitrates and the Ordnance Department" is assistant to the Chief of Ordnance and is Chief of the Technical Staff of the Ordnance Department. General Joyes was Chief of the Nitrate Division during the War and was personally connected with the various activities which led up to the construction of the several nitrate plants. His article is a brilliant discussion from the Ordnance viewpoint.

COLONEL E. C. PECK, General Manager of the Cleveland Twist Drill Company, is the author of the article on "Gages: Their Importance in War and Peace." He served with distinction during the World War as Chief of the Gage Section, Engineering Division, Office of the Chief of Ordnance. Colonel Peck is one of the few recognized authorities on the subject of gages for Ordnance manufacture and his discussion of the subject is authoritative.

MAJOR J. K. CRAIN, who writes on "The Muscle Shoals Situation" is Chief of the Ammunition Division, Office of the Chief of Ordnance and as such is in immediate control of the great plant at Muscle Shoals. He presents here a timely description of the entire project and recites facts which, we believe, are not usually known to the readers of ARMY ORDNANCE.

DR. ALFRED T. LARSON is a research chemist at the Fixed Nitrogen Research Laboratory. His article on "The Synthetic Process of Nitrate Fixation" describes a well-known process upon which a great deal of the success of adequate nitrate stocks depends. The Fixed Nitrogen Research Laboratories are doing excellent work in furthering the research work along these important lines and much credit is due to the men, of whom Dr. Larson is not the least, who are responsible for it.

COLONEL FRED H. WAGNER, author of "Benzol and Toluol for the Next War," is Chief Engineer of the Bartlett-Hayward Company and is considered one of the foremost experts on the subject of gas stripping plants in this country. Colonel Wagner did excellent work in this connection during the War while serving in the Ordnance Department.

DR. WILLIAM H. ROSS, author of "War-time Nitrate for Peace-time Agriculture," is a chemist in the Bureau of Soils, Department of Agriculture. He served as a captain in the Chemical Warfare Service during the War and did some very valuable work at the toxic gas laboratories at Edgewood Arsenal. Dr. Ross is now in charge of the concentrated fertilizer investigations at the Bureau of Soils laboratories at Arlington Farms, Virginia.

"Notes on Localized Enlargements of Machine Gun Barrels" is the work of CAPTAIN W. W. DE SVESHNIKOFF, a member of the Ordnance Section at the Bureau of Standards. Dr. de Sveshnikoff has on several occasions in the past contributed to these pages on subjects connected with rifle barrel erosion. He was a member of the Russian Military High Commission to the United States in 1916-1917. He is now an assistant physicist at the Bureau of Standards where he is engaged in research work for the Ordnance Department.

COLONEL HARRY W. MILLER completes in this issue his most interesting discussion of the "German Long-Range Gun," Part I of which appeared in the September-October number of ARMY ORDNANCE. Colonel Miller served in the Artillery Division of the Ordnance Department during the War and is now a member of the faculty of the University of Michigan.

MAJOR R. L. AVERY, who writes on "Artillery Ammunition," is stationed at Picatinny Arsenal where all ordnance activities connected with artillery ammunition are carried on. Major Avery is entirely familiar with his subject and writes with a definiteness of purpose that makes his recommendations and suggestions of great value.

MAJOR A. M. PRENTISS publishes in this issue Part II of his treatise on "The Specific Heat and Thermal Diffusivities of Certain Explosives," Part I of which appeared in the September-October issue of ARMY ORDNANCE. Major Prentiss has done some excellent work in the Chemical Warfare Service, as this discussion indicates.

Back Numbers of Army Ordnance

WE regret to announce that our stocks of several of the back numbers of ARMY ORDNANCE are exhausted. Numbers 1, 2, 3, 4, 5, 7, 8, 9, and 17 are now out of print. Many requests have been received recently for complete volumes and we have been unable to supply them. Any members who have retained back files of the magazine and who wish to dispose of these numbers should communicate with the Secretary, Army Ordnance Association, 410 Munsey Building, Washington, D. C.

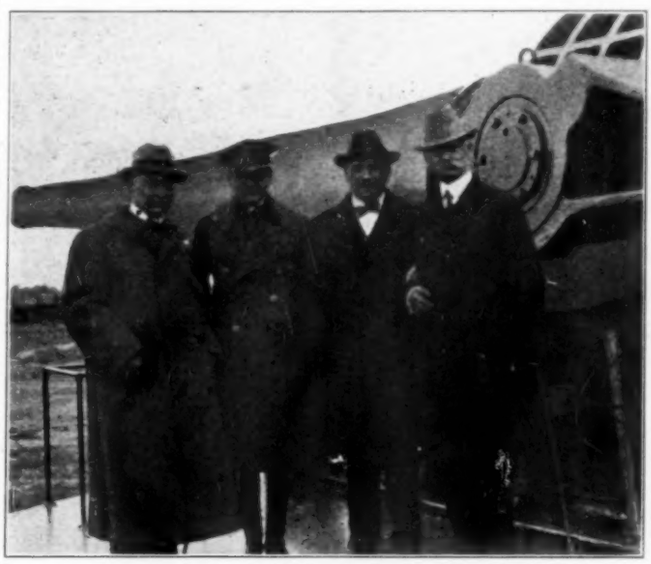
The Fifth Annual Meeting at Aberdeen

THE Fifth Annual Meeting of the Army Ordnance Association at Aberdeen Proving Ground, October 26th, was one of the most interesting and significant gatherings in the annals of national defense in recent years. This is so if for no other reason than that at the meeting Judge Elbert H. Gary, President of the American Iron and Steel Institute, reaffirmed in a stirring address the willingness and desire of the steel industry to cooperate with Ordnance in assuring adequate preparedness in peace and cooperation without limit in war.

The meeting was participated in by the Iron and Steel Institute, which was represented by several hundred members who journeyed to the Proving Ground and by their presence and assent added their indorsement to the important work of industrial preparedness.

Thus it can be said that the Fifth Annual Meeting was one of the most important demonstrations of the things of war since the days of 1918.

In addition to the large attendance of the steel men, the meeting brought out larger numbers of Army Ordnance followers than ever in the past. It has been conservatively estimated by officials at the Proving Ground that more than 1,200 were in attendance. From Washington came the Assistant Secretary of War, Colonel Dwight F. Davis; General C. C. Williams, Chief of Ordnance; General Mason M. Patrick, Chief of Air Service; General Amos A. Fries, Chief of Chemical Warfare Service; General Rockenbach of the Tank Corps, and General Crozier, former Chief of Ordnance. From New York in special trains came a large delegation headed by Judge Gary, Charles M. Schwab, James A. Farrell, and E. A. S. Clarke of the Institute. Likewise from Philadelphia, Boston, Baltimore, Cincinnati, Cleveland, Chicago and Detroit came members to attend the meeting.



Judge Gary, General Williams, Charles M. Schwab and General Crozier at the Aberdeen Meeting

The program, which was materially different from that of previous years began at 10 a. m. at the seacoast front. The 16-inch gun on Barbette carriage, the largest gun in the United States, and the 14-inch gun on the Army railway mount, the latest development in railway artillery, were fired. Armor plate penetrated by the 14-inch armor-piercing projectile was exhibited. The 8-inch howitzer, model 1920, with split trail, and the 155 mm. gun on self-propelled mount were next maneuvered and fired.

A demonstration was given by a detachment of coast artillery troops firing the 3-inch antiaircraft gun, model 1918, at a target towed by an airplane. Six-hundred-pound demolition bombs were dropped on water from a Martin bomber at an altitude of 2,000 feet, and aircraft machine gunners destroyed miniature balloons in the air. The various types of aircraft used at the Proving Ground were next demonstrated as also were the various kinds of bombs of both domestic and foreign manufacture.

At noon luncheon was served in the Visitors' House after which short addresses were given by several of the distinguished guests who were introduced by Honorable Benedict Crowell, former Assistant Secretary of War, and President of the A. O. A. since its foundation. The Assistant Secretary of War, Mr. Davis, who was the first speaker, said, in part:

"It is a great pleasure to me, both personally and in my official capacity as the Assistant Secretary of War, to see so many of the business men and engineers of the country, and especially such a large representation from the steel industry, present at this meeting of the Army Ordnance Association. It shows that you are vitally interested in the great problem of industrial preparedness. And I must tell you frankly that, without such wholesome interest on the part of industry, our efforts at industrial preparedness would achieve but little.

"I feel that I should not neglect this opportunity of giving you just a bird's-eye picture of what the War Department is endeavoring to accomplish in the way of industrial preparedness, in the hope that you will help the work along as opportunity presents itself.

"The principles underlying industrial preparedness are similar to those underlying man-power preparedness. We must have sufficient man-power trained and ready to fight and able at least to protect the country until it can develop the necessary reinforcements from the civilian body. This force from a standpoint of economy should be the minimum necessary to accomplish this objective. The better the plans for the early development of reinforcements the smaller may be the permanent force necessary. The plan for developing reinforcements of man-power through the National Guard, the Organized Reserves, the R. O. T. C., and the C. M. T. C., is one of the most important provisions of the present military policy of the country, as outlined in the National Defense Act of 1920.

"In the same way, we must have sufficient stocks of all supplies available for the Army to fight with, and, particularly, stocks of important items of fighting equipment, such as aeroplanes, rifles, artillery, and bombs and ammu-

nition therefor, until reinforcements can be developed; or in other words, until the production of the industries of the country can be made available in ample quantity. And these materials, in order to give our army a fair chance, should at least equal in quality those available to our enemy—and this Proving Ground which you are visiting today is one of the agencies at work to accomplish this part of the mission. Again, from the standpoint of economy, the reserve stocks should be the minimum necessary to accomplish the objective and no less. And in this problem also, the better the plans for obtaining the early production of the industries of the country, the less reserve stocks are necessary. The National Defense Act likewise provides for this phase of the problem and charges the Assistant Secretary with making adequate arrangements for mobilizing the nation's resources.

"The question of the reserves to be retained, maintained, or developed is one to be settled by the Congress, for it entails appropriations of money. But the problem of industrial mobilization is one that can be planned by the War Department in conjunction with the country's industries, for the expenditures are relatively small.

"The problem of Industrial Mobilization can be divided into three main questions: What must we procure? Where can we procure? and How will we procure?

"In answering the first question, 'What must we procure?' we know that the war requirements depend upon the size and rate of mobilization of our probable war army, the initial supplies of all kinds required by such an army and the probable rate of consumption of such supplies. These assumptions are strictly military and must, therefore, be made by the General Staff. They have already been made and, in accordance therewith, the seven supply branches into which the Army is divided have practically completed the calculations of the requirements by months, amounting to some 23,000 major items and some 700,000 total items. If from these we subtract our reserves, we definitely define our quantity procurement programme and this can be worked out to develop in turn the quantities of steel, copper, nitrates, powder, explosives, etc., required. And if, in addition to quantities we have definite specifications developed (and this phase of the task is being expedited), we know in reasonable detail what our war problem is, based upon the assumptions made. Even if these assumptions are changed, we can quite easily modify our requirements. The calculation of requirements is in itself a long step forward on the road to preparedness, if nothing else were done. If it had been made before the World War, it would have saved months of time and literally billions of dollars.

"The answer to 'Where can we procure it?' is dependent upon the ability of the country to produce. It is the desire of the War Department to spread the industrial load throughout the country on the basis of the country's industrial capabilities. The country has, therefore, been divided into districts and each chief of a Supply Branch is endeavoring to ascertain through his chief of district the ability of that district to help him solve his war problem. With the knowledge thus obtained, it is possible to allocate definite war orders to particular plants. This survey is extremely valuable in getting the War Department acquainted with Industry and the beneficial results therefrom are far reaching.

The Fifth Annual Meeting of the Army Ordnance Association, The American Iron and Steel

"Many of you have undoubtedly come into contact with War Department representatives engaged in this work. I hope that you will give them a helping hand.

"The answer to 'How will we procure?' has many parts. While procurement responsibility for the items he is required to furnish rests with each Chief of a Supply Branch, there are many common problems. Among other things standardized war contract forms would be desirable, and these are being worked out on the basis of world war experience after consultation with hundreds of business men. A sound and expeditious scheme for payments is likewise being studied. Plans are being studied to avoid conflicts between Branches of the Army and between Departments of the Government as to use of specific plants, and as to priorities in raw materials, power, labor, transportation, etc. An Army and Navy Board is in existence for allocating plants as between the Army and Navy, and my office has allocated some 3,000 industrial plants to particular Supply Branches which, in turn, have allocated them to their various districts. Proper control records for the purpose of coordinating procurement are being worked out.

"But, above all, efficient personnel to carry out the

plans is an absolute necessity. Each Chief of a Supply Branch and the Staff of the Assistant Secretary will need many men of ability, well trained through either Army schools or industrial experience, or much better through both, to satisfactorily accomplish the desired objective. The Army is concentrating on a schooling system to train its supply officers in the war plans and in the proposed methods of executing them, but the regular officers can man only a small part of the organization in time of war. Business men, engineers, reserve officers, in fact, just such men as you gentlemen who are today attending the meeting of the Army Ordnance Association will have to do the bulk of the work in connection with Industrial Mobilization in time of war. I sincerely hope, therefore, that you will keep up your interest in the great problem of preparing the country industrially for a maximum war effort, because upon its sound solution may depend the saving of billions of dollars, thousands of human lives, and the economic welfare of the nation."

Institute Participating, Aberdeen Proving Ground, Maryland, October 26, 1923

Judge Gary, the next speaker, then gave his address which, by many present, was declared the most far-reaching pronouncement toward national security since the War. Judge Gary said, in part:

"In behalf of the American Iron and Steel Institute, so well represented here today, I assure the Army we are very grateful for the courtesies extended, which we have so much enjoyed. And we are glad to know that our industry is recognized as important in the defenses of this great country, and in the effort to establish military preparedness if and when it may be necessary.

"Every country solicitous for the welfare of its people, desires to establish and maintain adequate military force. This is of first importance for protection of a country and for prevention of war. Every good citizen appreciates that our country has always been opposed to war, opposed to military conflict, but at the same time believes we should be prepared to fight any and everywhere, and to make perfect the defenses needed. Soldiers, the greatest and most competent to fight, are always strongest for peace, but not to the extent of preventing their being ready for defense; and they are always ready to fight to the uttermost if and when it becomes necessary.

"Soldiers of America are naturally gentlemen. The habit of being a gentleman grows from the time of entrance in the Military Academy or enlistment in the voluntary army. Proverbially, the American soldier does his military duty in such a way as to command the affectionate interest of his countrymen. Moreover, the soldier equipped for fighting is also a good business man. This we found much to our gratification during the war.

"We congratulate the gentlemen of this society, under whose auspices we are here. We have been much surprised this forenoon by what you have shown us. We of the Institute know little of the work of the soldier, but we have sense enough to appreciate by observing these exhibits what you are doing.

"During the dark days of 1917-1918, when this country was forced to enter the great international conflict, the Secretary of War and the Secretary of the Navy called into conference the leaders of the iron and steel industry of this country for its vital aid in the way of munitions, and I am proud to say on behalf of the great industry with which I am associated, that it responded immediately, cheerfully, and whole-heartedly to that call of the nation. I believe I say accurately that while the industry faced a great problem in meeting this call so suddenly thrust upon it, not once during the terrific struggle, when resources were being strained to the utmost, did our military forces suffer in any of their endeavors on account of a lack of appreciation or of an intelligent disposition to meet the needs of our Army and our Navy for adequate munitions and supplies. And may I add, though perhaps it may seem unnecessary, that should in the future our beloved country again be thrust into the necessity for national defense, that the iron and steel industry will again promptly and with vigor meet the situation to the utmost of its ability. We have in the United States a total capacity for steel production greater than that of any other country, greater, indeed, than the combined capacities of all the other countries, and I wish you gentlemen of the Army to know that in your studies of preparedness for national safety that the iron and steel men are behind you with their sympathies, abilities and resources. I congratulate you again, General Williams and your associates, and you gentlemen of the Army Ordnance Association, on the great and val-

uable work you are engaged in, as so interestingly and capably displayed here today. And I wish again to thank you for the opportunity given us to see, at least in a measure, the results of your efforts, and to assure you once more of the sincere co-operation of the iron and steel men of this great country of ours, both as individuals and through the American Iron and Steel Institute.

"The American soldiers, from the time of their independent, unassisted and successful attack at Cantigny to the close of the great battles of Argonne Forest, which broke the back of the German army, demonstrated they were as fine a body of fighting soldiers as the world ever witnessed, and they excited the admiration of all their allied associates. They can be depended upon in any emergency that may arise. And the iron and steel industry of the United States will be pleased to act as an auxiliary in providing all the iron and steel that may be needed. Rely upon us to do our part and you will not be disappointed."

General Ruggles and James A. Farrell, President, U. S. Steel Corporation, at the Meeting

It is to be regretted that there was no reporter to take down the remarks of Mr. Charles M. Schwab, chairman of the Bethlehem Steel Corporation, who was the next speaker. His was a talk—at times in a lighter vein than the preceding speakers—but a classic of good cheer, renewed friendships, and optimsism. The address will be remembered by his hundreds of hearers as a feature of the gathering that bespoke the caliber of one of our foremost citizens.

General Williams then spoke. As Chief of Ordnance he welcomed the guests and thanked them for their interest and co-operation. He pointed out the great importance to the country of the sustained support of our industrial leaders in insuring adequate preparedness.

The afternoon program at the main front consisted of demonstrations of the following automotive matériel: the medium tank, models 1921 and 1922, the Mark VIII tank, with Stroboscope, and a radio-directed 6-ton tank. Tractors on exhibition consisted of the 2½-ton, Model 1920, the 2½-ton, Model 1918, the Best "30" towing 4.7-inch gun, Model 1906; the Holt T-35 towing ¾-ton trailer; the Pavesi towing the 3-ton trailer; the Fordson with Hadfield-Penfield adapter towing cargo carts, and the 5 and 10-ton artillery tractor towing 155-mm. gun and howitzer. The Topp-Stewart tractor towing the 3-ton convertible wheel and track-laying trailer was also exhibited. The various motor carriages were shown and demonstrations of cross-country trucks included the 6-wheeled Militor, the Dodge truck with Chase track, the Nash with caterpillar adapters, the Roadless Mack truck and the Christie Mack. The following small arms and infantry weapons were exhibited: Garand Semi-automatic Rifle; Springfield Rifle, Model 1903; U. S. Rifle, Model 1917; Browning Automatic; Browning Machine Gun; Browning Aircraft Machine Gun; Browning Machine Rifle, with Tripod; Lewis Aircraft Machine Gun; Thompson Gun, Caliber .45, Military Model; Thompson Heavy Autorifle, Caliber. 30. Browning Machine Guns, ground and aircraft types. 37-mm. Semi-automatic Cannon. Infantry Cannon: 37-mm. Gun, Model 1916; 37-mm. Gun, Model 1923E; 2.24-inch Infantry Mortar, Model 1922E; 75-mm. Infantry Mortar, Model 1922E; 3-inch Stokes Trench Mortar. There was a demonstration by the Sixth Field Artillery of firing of smoke shell at fixed targets. There was also an exhibit of smoke screen as laid down from an airplane. In the late afternoon there were firings of tracer ammunition and flashless powder.

At 5:30 p. m. the business meeting of the Association took place, Mr. Crowell presiding. There were several hundred members in attendance and much enthusiasm was displayed. The Secretary gave a brief résumé of the present status of the Association, after which there was an open discussion of Association activities, and with adjournment came a feeling that this was a "real" meeting.

Mr. Crowell, Colonel R. P. Lamont, of the American Steel Foundries; Colonel C. L. Harrison, Chief of the Cincinnati Ordnance District; Mr. William W. Coleman, President of the Bucyrus Company, of Milwaukee, Wisconsin, and General Colden L'H. Ruggles, Chief of Manufacture, Ordnance Department, addressed the meeting. Plans were made to begin a campaign to secure new members and to broaden the scope of the work of the Association. The officers elected for the coming year were then installed. As previously announced they are: President, Benedict Crowell; Vice-President, William W. Coleman; Directors (to serve until October, 1925), General Guy E. Tripp, General Samuel McRoberts and Mr. Waldo C. Bryant.

Dinner was served at 6:30 and at 7:30 the special trains pulled out for New York, and the fifth annual meeting, the biggest and best so far, was history.

Nitrates and the Ordnance Department

By

BRIGADIER GENERAL JOHN W. JOYES

WHAT has been the purpose of the Ordnance Department in its course of action in connection with the nitrate problem? What has been its course of action? What have been the results?

The interest of the Ordnance Department in nitrates lies exclusively in the provision of an essential constituent of the military explosives necessary to the defense of the United States. Whether such material be dug out of the ground in the United States or in a foreign country, or the necessary material be produced by manufacture by this, that or another process, or whether facilities for such production be controlled by a fertilizer manufacturer, an automobile manufacturer, a hydro-electric power company, or by the United States itself, the Ordnance Department has been, and is, in a disinterested and impartial position, except as such conditions of source, method or control may cause exorbitant cost of the material or affect the reliability of its supply.

General Joyes

That measures taken to ensure nitrate supply for military defense may excite local ambitions for public work in certain localities, or arouse hopes of a large section of the country for improvement of navigation, development of water power, production of more and cheaper fertilizer — is no concern of the Ordnance Department, except as such non-military collateral influences may affect the practicability of measures to ensure provision of the military necessities. Thus, it is fortunate for the military protection of the country if works for producing nitrates incidentally so benefit navigation that part of their first cost may be properly charged to improvement of navigation, or if the product of these works may, in the interval of peace between wars, be sold at prices sufficient to maintain the plant in going condition —if, in other words, the works can earn their keep. The Ordnance Department has endeavored to point out opportunities and means for thus obtaining the military preparedness deemed necessary; but any such plan must involve conflicts of interest and questions of public policy in which the Ordnance Department should not and does not adopt any attitude of partisanship.

Nitrate Supply

Action upon the problem of nitrate supply began many years ago, although it is but recently that it has excited any considerable public interest.

In the days of black powder, all the countries of the world that desired to indulge in the military use of black gun powder were required to think of potassium nitrate, commonly known as niter or saltpeter, as a critical constituent, the supply of which must be provided for and safeguarded. This material occurred in considerable quantity mainly in India. In other places it was found in small quantities and it could be made by artificial methods, but in those days these methods were crude and too cumbersome to be satisfactory for a supply of any magnitude. In those days most countries realized this fact and safeguarded their military future by importing in peace times considerable quantities of saltpeter as a war reserve supply.

In 1829 the Chief of Ordnance of the United States Army advised the accumulation of a reserve of three million pounds of saltpeter, expressing his "conviction that it is of great importance." He made special mention from year to year of the amount accumulated and in 1846 reported the reserve as 3,368,681 pounds— "enough for five million pounds of powder."

In 1864, the Chief of Ordnance featured in his report the situation as to saltpeter, stating that fifteen and a half million pounds had been purchased in the three war years preceding at prices abnormally high because of our large demand and urgent need; he reported as then on hand eight million pounds and advised purchase of three million in addition—"if to be had at reasonable price."

In 1871, the Chief of Ordnance in his Annual Report "renews previous recommendations" for a depot for the storage of niter, and in 1879 his report shows a reserve of 3,000 tons—six million pounds—of this substance.

Saltpeter, or niter, or potassium nitrate, while it enters into black powder as simply one substance mixed with another, is present therein for precisely the same purpose that Chile saltpeter, that is, sodium nitrate, serves in the manufacture of the chemical compounds which are our modern explosives—namely, smokeless powder, nitro-glycerin, TNT, ammonium nitrate, etc. Its function is to bring into the mixture or compound the oxygen required for combustion, and upon ignition to release the oxygen and make it available in the nascent state, in which it combines most readily with the carbon, hydrogen, etc.

When, therefore, smokeless powder and the other modern explosives superseded almost entirely the black powder formerly used, "Chile saltpeter," or sodium nitrate, assumed the place and character as a military necessity that saltpeter had previously held. There was a further analogy in the restriction of supply to practically a single locality upon the earth's surface. In this case it was not India but Chile where a certain combination of conditions had caused a large area to be underlain by more or less rich "caliche," which might be called sodium nitrate ore. During peace times, the importation from Chile of sodium nitrate produced from this caliche had given rise to no particular difficulties except economical ones due to the monopolistic control of selling price, the high cost of transportation and the export tax (usually about 20 per cent of the total cost) which is imposed by the State of Chile and constitutes in fact the principal source of revenue of that State. Every country, other than Chile, however, must take note of the fact that in case of war it may have to pay exorbitantly for its supply from Chile, or that supply may be cut off completely from one or another cause. Aside from physical difficulties and delays, shipping requirements and so on, there is danger that an enemy may control the sea-route from Chile, or that Chile may be hostile or so influenced by hostile powers as to place an embargo upon nitrate exports.

Such a condition naturally indicates the advisability of providing against excessive charges or the more serious total interruption of supply by some means—the most obvious of these being to lay in in the home country a reserve to be used only in a period of war.

Having in mind such considerations as the foregoing, and recognizing the lack of any alternative source of supply of adequate quantities, the Chiefs of Ordnance, between the time of the Spanish War and the entrance of the United States into the World War, did recognize and represent to their superiors the need for a reserve of sodium nitrate in the United States. In so far as Congressional appropriations permitted, this was done, and when we entered the War in 1917, the reserve was about sixty million pounds.

Nitrate Fixation

However, even before the World War, the Ordnance Department's studies indicated a disadvantage, in fact a danger, in having no provision for the supply of nitrate for a war of possibly long duration, other than an accumulated reserve; and the Chief of Ordnance took note, early in the present century, of the keen interest abroad in the new technical processes for artificial production of nitrogen compounds—commonly called the fixation of atmospheric nitrogen.

These new processes were based upon chemical reactions long known to chemists, but unused because of lack of favorable technical and industrial conditions. About 1900, there was a two-fold incentive for the development of these processes; first, the growing demand for nitric acid and nitrates for many purposes, which with the growing cost of production and importation and the monopolistic combination of producers and sellers, was raising the price of Chile nitrate and encouraging the hope of profit for a competing product; second, a series of publications—propaganda, perhaps, but backed by names of scientific prominence—which predicted the early exhaustion of the Chilean deposits, or in other words the whole world's early deprivation of nitrate.

Although these utterances are now considered as expressing alarmist and exaggerated views, they had undoubtedly this much of truth—that the richest and most easily and cheaply worked deposits were exhausted and that from year to year fields of less and less nitrate content, more and more distant from the ports, must of necessity be worked, with resultant rise in cost. At any rate, they incited commercial research, and stimulated the working out of processes and the building up of plants.

By 1905, a company with mainly German and French capital had a going plant in Norway, where waterpower was cheap, in which several types of furnace were tried in the direct process—combining the nitrogen and the oxygen of the air.

Our Ordnance Department sent one of its officers, Major W. W. Gibson, to inspect and report upon this plant in 1906. Two years later, General Crozier, then Chief of Ordnance, asked the General Staff to obtain further information as to this plant, saying that this process held out hope of doing away with importations and with the war reserve of nitrate. In fact, he continued to observe the growth in Europe of this and other fixation processes with interest—on the watch for such a stage of development as would give opportunity for some action in behalf of American preparedness.

The calcium cyanamide process acquired prominence in Europe, especially in Germany, and American rights were secured by Mr. F. S. Washburn, who founded the American Cyanamid Company, and built a plant at Niagara Falls in Canada.

Professor Haber in Germany prosecuted laboratory research in the synthetic production of ammonia by direct combination of nitrogen and hydrogen, and the Badische Analin und Sodafabrik in Ludwigshaven and Oppau worked diligently in the three years before the war to perfect the technic for large-scale use of this reaction. Upon their success depended largely the ability of the Germans to carry on war for four years after their importations were stopped. But this process was intricate and most of its details were kept secret.

American rights to the Birkeland-Eyde process—the one used in the big Norway plant at Rjukan and the best of the arc processes—were acquired by the DuPont Company who never found place and conditions sufficiently favorable for their use.

A fertilizer company, in which Mr. Duke was interested, built a small Pauling arc plant in Carolina but it was never used largely. Another arc plant, of different type, was, and is, operating upon a cheap water power near Seattle.

But the industry had never taken root in the United States in such a way as to constitute any reliable source of supply of nitrates for war needs.

About 1915, the Chief of Ordnance, General Crozier, noting the large consumption of explosives in the European war and deducing therefrom the large quantity of sodium nitrate required, became convinced of the diffi-

culty of securing an ample supply for war by means of a reserve. He suggested the possibility of establishing a nitrogen fixation plant, or plants, essentially for the safeguarding of the military supply against the needs of war, but looking to the possibility that such a plant might maintain itself in time of peace by the manufacture and sale of fertilizer. He was careful to avoid recommending any particular process, or any particular form of agreement.

The National Defense Act

About this time a number of bills were introduced in Congress by many different members looking to the establishment of such plants, generally contemplating the use of Muscle Shoals power and more or less participation by the United States. There were many hearings on these bills and some of them attracted quite a following. There was a bitter attack upon them, on the other hand, from Northern Republicans who opposed spending money in the South for what some of them termed "subsidizing of cheap fertilizer for the Southern farmers." They were all regarded as lost—when in the closing days of the session, the National Defense Act, assured of passage, had attached to it as a committee amendment the Section 124, which authorized the President to investigate means for producing nitrates for "munitions and fertilizer" and providing twenty million dollars for development of such means, including power and other developments.

The action taken under and in connection with this Section of this Act—the investigations by special agents in Europe, the studies by committees and the inspections of sites by the Interdepartmental Board—the establishment of the Nitrate Division of the Ordnance Office, its building of the Nitrate Plant No. 1 for trial and development of a synthetic ammonia process, and its other installations and research—has been elsewhere described in detail. So have been also described the one large plant completed and the two others half built during the war to meet the war demands—using the cyanamide process as most certain of immediate reliable result in preference to any new and untried process, however promising.

The building of the Wilson Dam by the Engineer Corps was ordered by President Wilson under the Nitrate Supply Section of the National Defense Act. With this the Ordnance Department had no direct connection, although it was in hearty accord with the power-development as an important potential factor in the future supply of nitrate for war.

To sum up, the activities of the Ordnance Department in the nitrogen fixation work since 1915 have taken three main lines toward three intermediate objectives—all tending toward the one main object of ultimate assurance of supply for the needs of future wars.

The first of these lines was directed toward the best immediate security practicable, and consisted of the accumulation of reserve stocks.

The second line of activity was the Department's work of research and of actual plant construction to try out processes of promise but not yet perfected or known in this country, with the object of stimulating and assisting the scientific and technical and commercial development of the art of fixation.

The third line embraced steps to meet an immediate need of the World War then in progress, with a partial annulling of our dependence upon precarious importations from Chile. The steps taken in this line were the construction of the great nitrate plant at Muscle Shoals and the commencement of two others in Ohio. The process chosen was necessarily that best calculated to yield with promptness and certainty the required supply. Future military usefulness, though not ignored, was secondary.

Such have been the purposes and such were the acts of the Ordnance Department. The results are gratifying.

This country had in 1919 stocks aggregating over five hundred thousand tons of nitrate, out of which there has been retained in the military reserve a quantity calculated to last from the outbreak of a war to the time when our home production can meet our needs. It has at Muscle Shoals a great plant complete, tested and kept in condition to produce promptly one hundred and ten thousand tons of ammonium nitrate per year.

Invaluable scientific and technical data upon fixation processes have resulted from research by Government agents or due to Governmental influences; such data are available for general commercial use.

That interest—not only academic but practical—has been aroused is shown by the building of two commercial plants using methods for the direct synthesis of ammonia.

Recovery of by-product ammonia from coking plants and gas plants has greatly increased, and the perfecting of practical methods for converting it into nitric acid has made this ammonia more generally useful for our needs.

We need no longer feel that for the nitrate supply for our defense we are dependent upon a foreign country or upon the adequacy and security of transportation over lengthy and exposed sea-routes.

A History of the Explosives Industry in the United States

The Institute of Makers of Explosives, which includes in its membership practically all the manufacturers of explosives in the country, is preparing a history of the explosives industry in the United States. This history is not to be a technical treatise, although it will naturally include a short account of important advances in the art, but will concern itself more particularly with the history of the different explosive plants, the companies that built them, and the men who were responsible for their success.

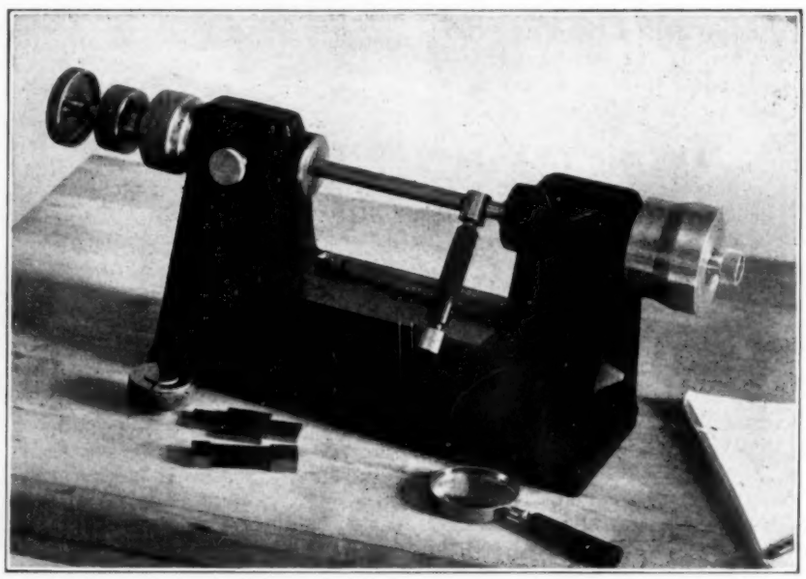
The committee, of which Mr. T. W. Bacchus, Vice-President of the Hercules Powder Company, is chairman, is anxious to secure data of the early days of the industry and its pioneers. It appeals to the readers of ARMY ORDNANCE to get in touch with Mr. A. P. Van Gelder (high explosives and black powder), or Mr. Hugo Schlatter (smokeless powder and military explosives), at 310 Delaware Trust Building, Wilmington, Del., if they have anything that might be of interest or help in this connection, such as personal stories of the pioneers, pictures of early plants, early catalogs or advertisements, etc.

Gages: Their Importance in War and Peace

By

E. C. PECK

ONE of the manufacturing weaknesses disclosed by the World War was the inability to obtain a suitable and uniform product from identical drawings and specifications. This was noticeable to some extent in practically all products and especially in what is known as munitions. The cause may be variously assigned, but, omitting any reference to profiteering, one of the troubles was the lack of understanding by the manufacturing public of everything pertaining to war munitions. The engineer and mechanic in the industries knew nothing of the manufacture or of the requirements of the various munitions. Outside the arsenals, mechanics had no way of becoming familiar with anything pertaining to the mechanical side of the war game, hence many of the important requirements from a military point of view appeared absurd and unnecessary.



Micrometer for testing diameter of plug gages

Friction resulted with consequent delay and annoyance where the specifications and drawings called for something peculiar or different from what the mechanic thought suitable. This feature could be corrected by keeping the manufacturing public in touch with the manufacture of war material either through the engineering societies or by having material constantly made during peace times.

Another source of trouble was the complicated specifications. There was a total absence of a standardized form of specifications and it was quite common to find the quality of a product specified as "commercial practice." This latter term depends entirely upon the judgment of the inspector. If he is used to a first class product, then he rules that kind is commercial practice. If he is used to a cheap, rough product, then he would pass most anything. The writer has long contended that specifications should be so clearly written that every requirement of the product should be called for in known measurable terms that admit of only one meaning. This would eliminate the argument that usually accompanies the making of a product a little different from that to which one is accustomed.

Difficulties of Manufacture in War

The greatest manufacturing trouble experienced during the war was in the production of screw thread products and the gages for controlling them. This was primarily due to the lack of a working standard with defined limits and the ignorance of manufacturers as to the exact limitation of the difference in the dimensions of a pair of correctly fitting parts, and the probable results of errors.

It is true we had the United States standard thread but this was a basic dimension without any prescribed deviations for manufacture. Many manufacturers had set up for their own practice a set of tolerances that made their product interchangeable with itself, but it would not interchange with that of another who had different deviations from the exact standard. Then, too, some manufacturers allowed their deviations above basic, others below, and still others were both ways.

This was the state of affairs when the United States entered the war and began to make interchangeable screw thread products on the greatest scale attempted. Every manufacturer thought that his particular system was the best and that it ought to be adopted by the War Department. Very few shops had thread gages and the actual measurements of these were an unknown quantity.

When thread gages to known dimensions had to be made in large quantities there were not a half dozen shops (outside the arsenals) in the country with the knowledge, experience, or the equipment to make them. Consequently, the manufacture of the necessary thread gages was of slow development and after these became available, the education of manufacturers to the proper use of them was slow and handicapped by previous bad practice.

The National Screw Thread Commission

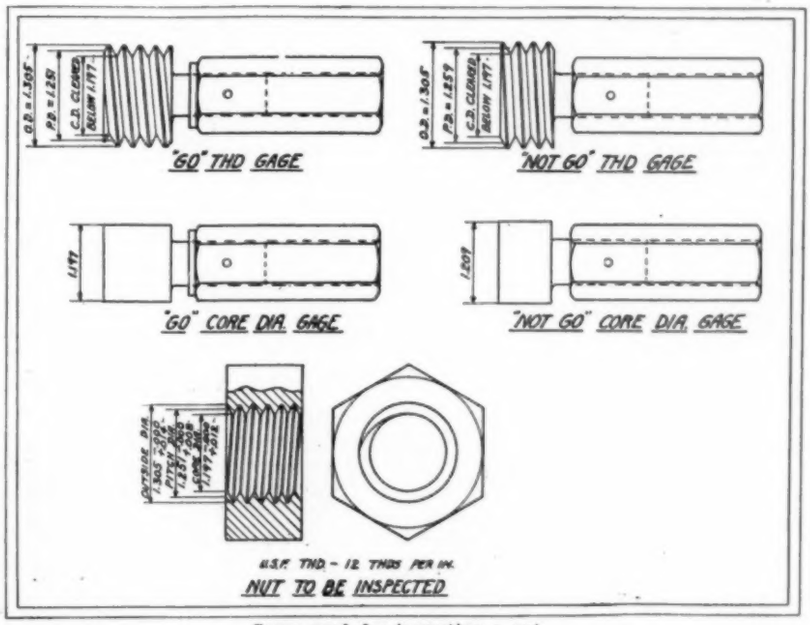
The screw thread trouble lead to the appointment by Congress of a Screw Thread Commission in July, 1918, and this Commission has standardized screw thread products in such a thorough manner that it can be put into use by any shop previously using the United States Standard, the Society of American Engineers' Standard, or the American Society of Mechanical Engineers' Standard without destroying the practical value of any tools or gages that were correct for any of the above-named systems, and the prod-

uct will be interchangeable. The system of screw threads shown in the progress report of the National Screw Thread Commission has been approved by the Government departments of Navy, War, and Commerce. It is now also before the American Engineering Standards Committee for approval, having been recommended by the special engineering committee appointed to review it. Therefore, in case of another war, one troublesome problem will be largely done away with.

One of the contributing causes to prevent economical manufacture on a large scale during the World War was the absence of standard allowances and tolerances for fits in other manufacture as well as screw thread product.

Any shop can make proper fits. Many of these fits would interchange with other work done in the same shop, but not with that of other shops. The most economical manufacturing process as a whole will be that where the common machine parts of the same nominal size will interchange and function properly wherever they are made. Such a condition necessitates a uniform standard practice as regards allowances and tolerances. For example, if a free running fit is wanted on ten thousand mating parts, the system by which the limiting dimensions of both the holes and shafts are determined must be the same for every shop producing any of these parts and then an order could be divided up among ten manufacturers making either member of the pair of mating parts and they would fit properly when assembled.

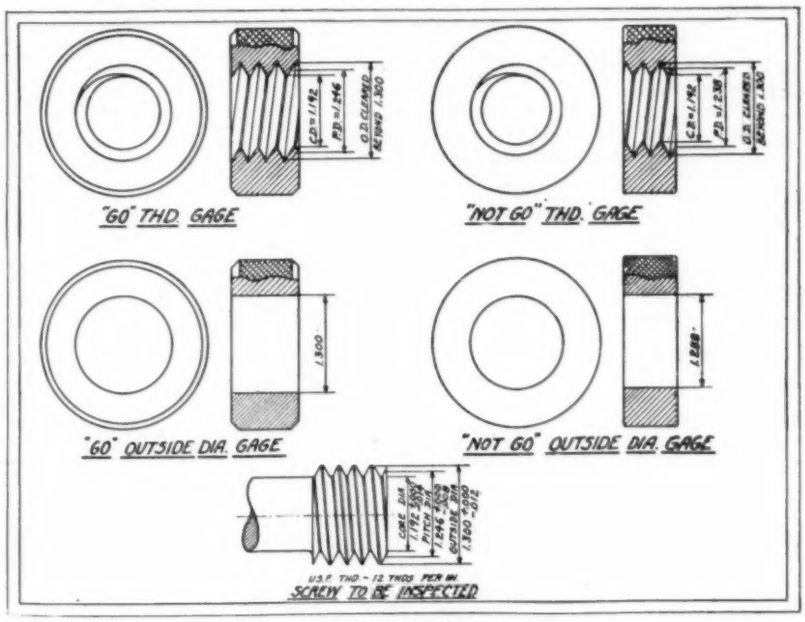
To make possible this uniform practice and provide a standard system of tolerances and allowances, the American Engineering Standards Committee appointed, in May, 1920, a sectional committee under the sponsorship of the American Society of Mechanical Engineers, known as the Flain Gage Committee for General Engineering Work.



Gages used for inspecting a nut

This committee after many public hearings and much research has submitted to the sponsor body (the American Society of Mechanical Engineers) for approval a progress report which contains tables of dimensions for eight classes of fits.

These tables are based on the practice of the best American shops doing interchangeable work. They are thoroughly practical and will produce interchangeable work. They are built on the fundamentals (1) that interference of metal begins at the basic dimension, (2) that component dimensions must never be exceeded either from gage wear or from any other cause. Based on what was learned in the World War regarding the production of interchangeable material, the standardization referred to above, especially that of the fitting of mating parts ought to practically eliminate most of the troubles which proved so embarrassing.



Gages used for inspecting a screw

Necessity for Centralized Gage Control

There is one subject that ought not to be overlooked in case of another war. In fact it is so important that it should be one of the first to receive attention—not the kind of superficial attention that starts a project as though it were a necessary evil, but a determined effort to start a vital necessity with an impetus that will carry it through. I refer to gages and the allied inspection equipment. The experience gained in the last war clearly points out the necessity of having one head to the entire subject of gages and under no circumstances should there be gage branches attached to various sections striving to operate independently. This was tried in the World War and operated inefficiently and with lack of economy. It prevents standardized practice

and causes confusion by competition between the branches for priority in procuring gages. It is obvious that the ability of one good executive gage man can be spread over one large section or division under his control with more economy and produce better results than can several men each at the head of a branch.

The procedure would be to procure the services of the best man attainable, put him in charge of and make him responsible for the design, procurement, and production of gages, together with their upkeep and checking.

Such procedure enables the Ordnance Department to begin at once the organization of an efficient unit and the transfer of the skill of one good man to every detail of the activity and thus prevent confusion and misunderstanding. It will enable the man in charge to properly organize the gage-making facilities of the country in such a way that each shop will be doing the kind of work it is best fitted to do. This is the method which will obviously enable an intensified effort to produce the best results.

Based on conditions existing at the beginning of the past war, if the next does not occur for a considerable lapse of time, there will probably again be a tendency to forget that gages, their design and procurement, are among the major divisions of the Ordnance problem co-ordinate with guns, carriages, and ammunition. *Gages are fundamental.* Without them interchangeable quantity production of Ordnance cannot be had. The Gage Division must be one of the first organized as it must function before the others can.

The California Post
of the
Army Ordnance Association

At the instigation of the section on National Defense of the Commonwealth Club of California steps have been taken recently to form a local post of the Army Ordnance Association at San Francisco. For this purpose a meeting of the members of the proposed post was held at the Palace Hotel, San Francisco, on October 17, 1923.

The meeting was called to order by Mr. Bruce Cornwall who was introduced as temporary chairman. Mr. Cornwall, in accepting the chair, made a brief address outlining in general terms the events since the War leading up to the meeting, and the experiences of the group of ex-officers who had attended similar meetings from time to time in the interests of Ordnance preparedness.

General Babbitt, Commanding General of the Ninth Corps Area, was announced as a guest and addressed the meeting briefly, expressing his hope that it would be successful in its undertakings and describing some of his experiences in Washington in the early days of the War, showing the necessity for a thorough organization in advance of an emergency. Major Kutz of the Ordnance Office, delivered the message of the Chief of Ordnance to the meeting and Major Partridge, Major Smith, Major Armstrong, and Mr. Weil addressed the meeting briefly. Mr. Cornwall then referred again to the purpose of the meeting—the organization of the California Post of the Army Ordnance Association. Colonel C. N. Black introduced the resolution providing for the organization of the California Post, which was seconded and carried. A second resolution was introduced authorizing the temporary chairman of this meeting to appoint the membership of the organization committee. The committee appointed consists of: Col. C. N. Black, Col. D. C. Seagrave, Major C. E. Partridge, Major M. L. Brett, Mr. F. T. Letchfield, Mr. Frederic Boegle, Mr. F. C. Metcalf.

The resolution providing for the organization of the Post was as follows:

WHEREAS, The Congress of the United States by the National Defense Act has provided for the creation of Reserve Armies, and,

WHEREAS, In the formation of the Ordnance Units of these Reserve Armies and the solution of such problems in connection with War Plans and industrial preparedness as may be assigned for local solution, there is an opportunity for the Army Ordnance Association and the Ordnance Officers' Reserve Corps to combine to offer assistance in the prosecution of such plans, and,

WHEREAS, It is highly desirable that the Ordnance Officers of the Regular Army, the National Guard, and the Reserve Corps be brought into intimate contact with the Army Ordnance Association which is pledged to support industrial preparedness, to the end that there may be mutual understanding and cooperation, and,

WHEREAS, A local association of both members of the Army Ordnance Association and Ordnance Officers' Reserve Corps will afford opportunity of maintaining the associations formed during the World War while serving in the Ordnance Department, be it

Resolved, That there shall be formed here a local organization which shall be known as the California Post—Army Ordnance Association;

That all Regular, National Guard, and Reserve Officers of the Ordnance Department, all members of the Army Ordnance Association, and all who served as officers in the Ordnance Department during the World War, shall be eligible for memberships;

That an organization committee be appointed to carry out the purpose of these resolutions in organizing this post, in conformity with the constitution and by-laws of the Army Ordnance Association.

Among those present were: E. B. Babbitt, Major-General, U. S. A.; Bruce Cornwall, M. L. Brett, Major, U. S. A.; H. R. Kutz, Major, U. S. A.; C. E. Partridge, Major, U. S. A.; T. J. Smith, Major, U. S. A.; S. P. Spalding, Major, U. S. A.; Chas. N. Black, H. O. Holt, Captain, O. R. C.; A. L. Weil, A. A. Ricker, Major, O. R. C.; Charles Walton, F. T. Letchfield, E. J. Fowler, C. F. Wieland, Major, O. R. C.; E. N. Wilkerson, W. O., U. S. A.; John H. Hall, Captain, O. R. C.; Theodore McPhail, Major, O. R. C.; Esmond Schapiro, 2d Lieutenant, O. R. C.; H. S. DeLancie, Charles F. Armstrong, Frederic Boegle, Jr.; N. W. Osborne, Captain, U. S. A.; W. A. Doble, Jr.; H. B. LaRue, Captain, U. S. A.; G. E. Frahm, 1st Lieutenant, O. R. C.; C. E. Stamp, Captain, O. R. C.; D. C. Seagrave, Colonel, O. R. C.; Dozier Finley, Captain, O. R. C.; F. C. Metcalf, Ralph L. Phelps, Charles Hoehn, F. J. Beheman, H. W. Crozier, Bruce Lloyd, W. E. Martin.

The Muscle Shoals Situation

By

J. K. CRAIN

THE fact that the United States was dependent upon Chile for its nitrogen supply was realized by the Ordnance Department long prior to the World War. This, with the isolation of Germany and the attempted isolation of Great Britain, emphasized the condition. The Chief of Ordnance in his annual report to the Secretary of War for the fiscal year 1915 called attention to the lack of production of nitrogen in the United States and that the only available source of adequate nitrogen supply was Chile. He pointed out the necessity for inquiring into the possibility of establishment within the limits of the country a source of supply of this war essential.

Colonel Crain

In 1916 Congress passed a National Defense Act in which Section 124, Nitrate Supply, reads, in part as follows:

> "Nitrate supply.—The President of the United States is hereby authorized and empowered to make, or cause to be made, such investigation as in his judgment is necessary to determine the best, cheapest, and most available means for the production of nitrates and other products for munitions of war and useful in the manufacture of fertilizers and other useful products of water power or any other power as in his judgment is the best and cheapest to use;
>
> "The sum of $20,000,000 is hereby appropriated out of any moneys in the Treasury not otherwise appropriated, available until expended, to enable the President of the United States to carry out the purposes herein provided for."

This act authorized such investigation as might be necessary to determine the best and cheapest means for the production of nitrates for munitions and fertilizer, and did not aim at filling any definite requirement of specific amount or material; in other words, immediate production was secondary in importance to the establishment of a process which would be useful for production in peace-times as well as in war. The Secretary of War was designated to carry out the provisions of Section 124 of the National Defense Act of 1916.

The work done falls into three main classes:

(1) Process investigations carried out by various agencies and those still being carried on by the Fixed Nitrogen Research Laboratory, Department of Agriculture,

(2) Initial work on construction of U. S. Nitrate Plant No. 1,

(3) Initial work on Muscle Shoals Dam No. 2. From the time when the United States entered upon its nitrogen fixation program, chemical research has been carried on under authority contained in Section 124, Nitrate Supply, National Defense Act of June 3, 1916. By 1919 this work had been organized into the Fixed Nitrogen Research Laboratory and was located on the grounds of the American University, Washington, D. C. Prior to July 1, 1921, this work was under the control of the Ordnance Department of the Army, but at that time the work being no longer directed mainly toward munitions but rather toward fertilizers, this laboratory was transferred to the Department of Agriculture. The laboratory is still carrying on research work along nitrogen fixation lines, financed with funds from Section 124.

The second step taken by the Secretary of War was the construction of a nitrate plant as a means in investigating the best way of producing nitrates for munitions of war and for fertilizer.

Before arriving at a decision as to the constructive steps to be taken, the Secretary of War appointed several committees made up of prominent scientists and business men to determine the best method for carrying out the provisions of the Act. It was finally recommended that a plant be erected for the fixation of nitrogen by synthetic ammonia process, and that the General Chemical Company's modification of the German Haber process should be used, contingent upon satisfactory arrangements with the General Chemical Company. Although the General Chemical Company's process had not been established on a successful basis, and only preliminary work thereon had been done, it was conceded that the establishment of this process which gave promise of low operating cost was thoroughly in accord with the purposes of the National Defense Act. Recommendations of

the committee also provided for the creation of a plant for the oxidation into nitric acid of a part of the ammonia to be produced by the synthetic ammonia process. These recommendations did not contemplate the manufacture of ammonium nitrate for use in munitions.

U. S. Nitrate Plant No. 1

As a result of long continued and thorough examination of sites, there was submitted to the Secretary of War on September 20, 1917, a report listing and giving the characteristics of nine sites, which appeared to be worthy of serious consideration. On September 28, 1917, the Secretary advised that the President had decided upon Sheffield, Alabama, as a site upon which Plant No. 1 should be built. This site is known generally as Muscle Shoals.

The recommendations concerning the construction of the synthetic ammonia plant led to an agreement with the General Chemical Company for the construction of U. S. Nitrate Plant No. 1. Construction was started in the late summer of 1917, in accordance with an agreement with the General Chemical Company, dated July 14, 1917, in which the General Chemical Company allowed the Government to make use of its process without the payment of royalty, if the production of the plant were used for munitions, or with the payment of a royalty of $5.00 per ton of fixed nitrogen, if the production were used in fertilizer. During the latter half of 1918 the plant was ready for operation but great difficulty was encountered in the synthetic ammonia process and this part of the endeavor was not a success. It was made to work periodically for a few days at a time, but always broke down. The remainder of the plant, however, including the ammonia oxidation plant, ammonium nitrate plant and nitric acid concentrator, was tested, using ammonia brought in from outside and was successful in producing the rated capacity of satisfactory material. The plant cost the Government approximately $13,000,000.

As the plant now stands it consists of a synthetic ammonia plant with a rated capacity of 30 tons of ammonia per day; a plant for the oxidation of part of this ammonia into weak nitric acid, with a rated capacity of the equivalent to 45 tons of 100 per cent nitric acid per day; a plant for the concentration of the weak nitric acid so formed to a strength of some 97 per cent, this latter process having a capacity of the equivalent of 12 tons of 100 per cent nitric acid per day; and a plant for the conversion of the ammonia and nitric acid into ammonium nitrate to a capacity of 22,000 tons of ammonium nitrate per year. There exists also a steam plant with a capacity of about 5,000 kilowatts. The nitrate plant contains 112 unfurnished permanent houses complete with furnaces, electric lighting and bathroom facilities; one unfurnished bachelor quarters of permanent construction with all improvements and containing accommodations for 35; 80 unfurnished temporary houses with no improvements (practically a construction camp); 8.6 miles of macadam roads; 8 miles of sewers; 4½ miles standard gauge railroads; water plant and other necessary auxiliaries. The site consists of about 1,900 acres.

The plant is, at present, in standby condition awaiting decision as to its final disposition and is costing the Government some $15,000 to $20,000 per year for maintenance. Although the Ordnance Department made quite extensive studies after the Armistice for the purpose of re-designing and re-constructing this plant in such a way that it would operate satisfactorily and believes that such an objective could be accomplished, yet the Ordnance Department does not recommend further expenditure on this plant for the following reason:

Making use of the experience gained at this plant, the Atmospheric Nitrogen Corporation, an affiliated company of the General Chemical Company and subsidiary of the Allied Chemical Corporation, has constructed and now has in successful operation a 10-ton ammonia plant following this general process, located at Syracuse, N. Y. In this way the purpose of U. S. Nitrate Plant No. 1, i. e., the establishment of the Haber process within the United States, has been accomplished and further expenditure at the plant would be only a duplication of the work which has been accomplished at Syracuse. The War Department does not consider this plant necessary for the achievement of munitions preparedness.

U. S. Nitrate Plant No. 2

The third step taken by the Secretary of War under Section 124 of the National Defense Act of 1916 was the initiation of Dam No. 2 at Muscle Shoals, also known as the "Wilson Dam."

When the site of Muscle Shoals was selected for the nitrate plants one of the prime reasons was the excellent potential water power available in the Tennessee River at that point. As a part of the original program, developed under the National Defense Act of 1916, the site for a dam was obtained and work is now in progress on the hydro-electric plant. A large part of the $20,000,000 made available by Section 124 of the National Defense Act has been expended upon this project. This dam has been described elsewhere and no attempt will be made in this article to deal with it in detail. It is mentioned here to give a complete picture of the relation that existed between the dam and the nitrate plant.

In the fall of 1917 the perfected military program called for quantities of high explosives greatly in excess of the existing capacity for production; therefore several large nitrate plants in addition to that known as No. 1 were planned. The first of these in priority was located at Muscle Shoals, a few miles from Sheffield, Alabama, and was given the designation "Nitrate Plant No. 2." This plant was a strictly war plant constructed under the authorization of war-time appropriations for the purpose, as stated before, of assisting in meeting the demands for explosives called for by the war. Therefore, Plant No. 2 was designed to produce the high explosive, ammonium nitrate, which was in turn to be combined with another high explosive, TNT., produced elsewhere in the United States. This mixture, which is called "amatol," is loaded into high explosive shells as a bursting charge.

Ammonium nitrate is formed by the union of ammonia and nitric acid. During the war there was a serious shortage of ammonia and a shortage was feared in Chilean nitrate from which nitric acid is ordinarily manufactured. The No. 2 plant was designed to fix the nitrogen of the air into the form of ammonia and then convert this ammonia into nitric acid. It was therefore able to assist in relieving the shortage that existed in ammonia and at the same time to reduce by a very considerable amount the quantity of nitrate of soda which must be imported from Chile and thus make available for transporting supplies to Europe a part of the ship tonnage engaged in bringing sodium nitrate from Chile. Furthermore, there was always a possibility of German submarines creating a serious condition by successful raids on the shipping between Chile and the United States.

In view of the purpose of this plant it was necessary to choose a process which could deliver with certainty the

ammonium nitrate required, even though the cost of production might be such as to render the plant of little or no value for operation in time of peace. Production was of utmost importance and therefore a thoroughly developed process was necessary. At this time the work of Plant No. 1 had not proceeded far enough to demonstrate the reliability of the process adopted for that plant.

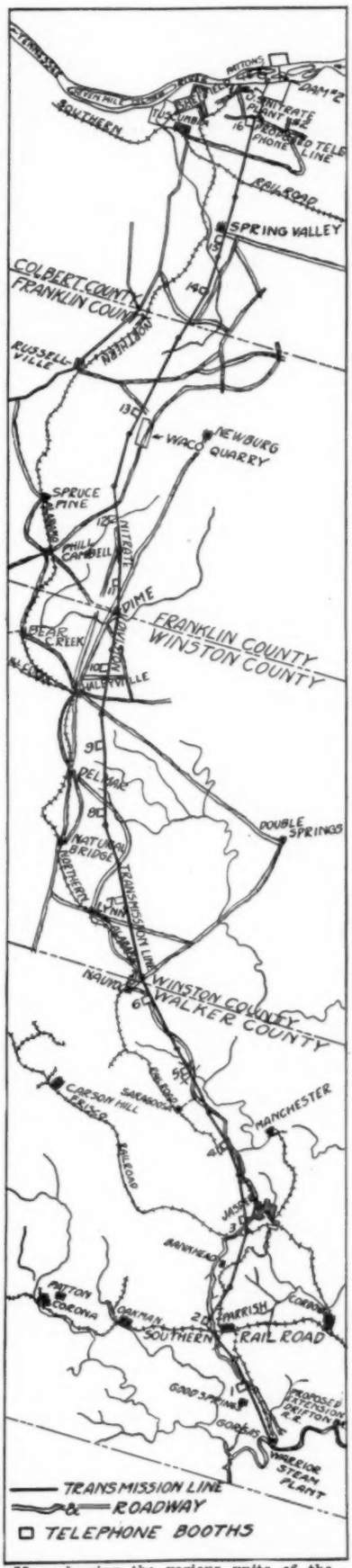
The American Cyanamid Company had been operating for several years the only successful nitrogen fixation plant on the American continent. The Government therefore selected the cyanamid process which was in use by this company at Niagara Falls, Canada.

Accordingly, the Government contracted with the American Cyanamid Company for the design and operation of the necessary plant. This company, in turn, organized the Air Nitrates Corporation as a subsidiary for the purpose of carrying out the contract with the Government. The final contract required the company not only to construct and operate plant No. 2 but also to construct and operate two additional nitrate plants, Nos. 3 and 4, the combined capacity of which would have been equivalent to the capacity of the United States Nitrate Plant No. 2. The contract with the Air Nitrate Corporation provided also that the corporation have the privilege of purchasing the plant upon as favorable terms as the United States is willing to accept from any other bidder. In this connection the United States also contracted with the Air Reduction Company for the use of its process in extracting nitrogen from air by the liquid air process.

Construction was started early in 1918 and was substantially completed at the time of the Armistice with the exception of the steam electric power plant. This latter was not ready for operation until August, 1919. The first operation of this power plant developed defects which were corrected and a final satisfactory test run was made in October, 1920. However, it should be remembered that the eight-hour law went into effect shortly after the Armistice and war-time speed in construction was abandoned. A test run of the chemical plant was made in the spring of 1919 and definitely proved that the plant was capable of producing its rated capacity of thoroughly satisfactory material. The cost of the plant amounted to some $66,500,000. The power used in the test run of the chemical plant came from the Gorgas Power Plant, which is described in a later paragraph.

The plant consists of a calcium carbide plant, including necessary facilities for burning limestone and preparing coke; a plant for the extraction of nitrogen from air by the liquid air process; a plant for the welding together of calcium carbide and nitrogen to form cyanamid; a plant for the conversion of cyanamid into ammonia; a plant for the conversion of half of the ammonia so formed into nitric acid; and a plant for the combination of nitric acid and ammonia for the formation of ammonium nitrate. The plant has a capacity of 475 tons of calcium carbide per day, 600 tons of cyanamid per day, 150 ton of ammonia per day, equivalent of 260 tons of 100 per cent nitric acid per day, and 300 tons of ammonium nitrate per day or 110,000 tons of ammonium nitrate per year. The capacity of this plant is five times the rated capacity of United States Nitrate Plant No. 1. It contains a steam plant, the housing of which is sufficient for 90,000 kilowatt generating equipment, but only 60,000 kilowatt capacity was installed. It contains 186 permanent houses with electric lights, sewers, and water supply; one hotel with 100 rooms with modern improvements and furnished; 366 temporary housing facilities; 22.3 miles of improved roads; 37 miles of standard gauge railway; 20 miles of sewers; 16 miles of domestic and fire water supply; a sixty million gallon reservoir, together with necessary filtering and pumping plant; and a 50-ton per day ice plant. The site consists of 2,300 acres of land.

This plant is being held by the War Department as reserve plant for the assurance of an adequate supply of nitrogen in time of need. With the exception of the steam electric power plant it is at present in standby condition. The 60,000 kilowatt steam plant is under lease to the Alabama Power Company, which company must maintain the plant in good condition. It pays to the Government a fixed rental of $10,000 per month and in addition two mills per kilowatt hour for energy generated at the plant. Under this lease the Government received from the Alabama Power Company during the fiscal year 1923 approximately $232,000 The total revenues received from this source and for the rent of building for the year 1923 amount to $241,300. The Government expended $67,700 during the year 1923 in maintaining and guarding this plant. The plant as a whole, therefore returned to the United States during the year 1923 approximately $173,600 over and above expenses.



Map showing the various units of the Muscle Shoals project

The Gorgas Steam Power Plant

United States Nitrate Plant No. 2 requires for its full operation approximately 80,000 kilowatts of power. It

was realized when the No. 2 plant was started that the construction of the required power plant would require a longer time than the development of the chemical plant proper. It was also desirable that an appreciable amount of power be available at an early date for construction purposes as well as for the initiation of operations. The Alabama Power Company was the only large producer of power in the vicinity of Muscle Shoals and therefore was the only company capable of delivering to the Government, at an early date, the quantity of power required. While this company was in a position to furnish power for construction purposes from existing facilities as soon as the transmission line could be constructed, it was not in a position to furnish any substantial part of the operation power requirements of Plant No. 2. However, at the company's 20,000 kilowatt plant on the Black Warrior River, plans had been made for an extension and certain of the foundations, water intakes, etc., were already installed, and on this account an extension to their plant could be completed in much less time than an entirely new power plant. Therefore, it was decided that two-thirds of the power requirements of Plant No. 2 should be supplied by a 60,000 kilowatt steam plant at Nitrate Plant No. 2 and one-third by a 30,000 kilowatt extension to the existing 20,000 kilowatt plant of the Alabama Power Company, located on the Black Warrior River, Gorgas, Alabama. Although this plant met with opposition from the nitrate plant contractor who contended that the whole 90,000 kilowatts capacity should be installed at the Muscle Shoals Plant site, the wisdom of the Government's decision was well brought out in November, 1918, when a portion of the nitrate plant was ready to operate, while the Muscle Shoals power plant was by no means ready to supply the necessary power.

A contract was therefore entered into between the Ordnance Department and the Alabama Power Company, providing for the construction of a transmission line from the company's system to Nitrate Plant No. 2 and providing further for the construction and operation by that company of the 30,000 kilowatt extension to their existing Gorgas plant, which assured to that company sufficient capacity to meet the added demand of the Government.

This contract provided in substance that these facilities would be constructed by the Alabama Power Company upon land belonging to the Alabama Power Company at the expense of the United States. The contract provided also for the Alabama Power Company to operate this plant and to supply power therefrom or from its system at certain definite figures outlined in the contract. In case the power plant was operated for the benefit of the Alabama Power Company only, that company was to pay certain rental to the United States for such use. The contract provided also that the plant would be sold to the Alabama Power Company after a certain lapse of time at a price to be fixed by a board of arbitrators, and provided further that in case such a sale could not be consummated, the plant would be removed from the land of the Alabama Power Company. The contract did not permit the Government to assign its rights in the matter of sale of this property.

Construction was started early in 1918 and power was available to the Government over the transmission line from the Alabama Power Company's system in May of that year. The power house extension was essentially completed at the time of the Armistice and power from this source was used for the test operation of Nitrate Plant No. 2 during January and February, 1919. The cost of facilities constructed on land belonging to the Alabama Power Company was approximately $4,780,000.

As already stated, the plant was constructed as an addition to the already existing plant of the Alabama Power Company, the Government unit and the Alabama Power Company unit being under the same roof. The Government unit has its own apparatus for supplying coal, its own apparatus for disposition of ashes, its own boiler plant, its own generator plant and its own switchboard. The trackage was mutually owned as was the water supply and the distribution system for taking the power from the switchboard. In addition to the power plant, there was constructed a substation for transmitting the power to the high voltage transmission line. There was also constructed a short railroad called "The Drifton Extension" for the purpose of connecting this site with a commercial railway. Housing facilities were also built by the Government.

These facilities were transferred to the Alabama Power Company on September 24, 1923, by sale by the Secretary of War, the sale price being approximately 70 per cent of the war-time cost.

The Warrior-Sheffield Transmission Line, which is approximately 90 miles in length, connects United States Nitrate Plant No. 2 with the Alabama Power Company's transmission system and the Gorgas Power Plant. The drawing herewith gives the relative positions of the Wilson Dam, the Nitrate Plants Nos. 1 and 2, the Waco Quarry, and the Warrior or Gorgas Steam Plant with transmission line connecting the latter plant and the nitrate plants.

Waco Quarry

The Waco Quarry was established to supply Nitrate Plant No. 2 with a large quantity of high-grade limestone necessary for its successful operation. Daily consumption of limestone at Plant No. 2 is some 1200 tons.

Waco Quarry is located near Russellville, Alabama, on a site consisting of about 450 acres which has been sufficiently explored to assure a sufficient quantity of high-grade limestone to supply Plant No. 2 for a period of 50 years.

United States Nitrate Plant No. 2 is the only one of the Muscle Shoals units that has a definite place in the present war plan of the Army.

Nitrogen Preparedness

The Ordnance Office believes that the best and only permanent solution of the nitrogen preparedness problem is to be found in the development of the nitrogen industry in the United States on a commercial basis by private enterprise. The country has made considerable progress along this line since 1915. The Haber process has been established within the United States and can be expanded when conditions require; the by-product coke industry has expanded until the present output of ammonia is approximately three times that of 1914; the increase since 1914 in the ammonia production from by-product coke ovens amounts to approximately double the capacity of the United States Nitrate Plant No. 2.

However, were it not for the existence of United States Nitrate Plant No. 2 the United States would still be largely dependent on imported nitrates for munitions manufacture, should an emergency arise, and it is therefore the policy of the Ordnance Department to preserve this plant as a nitrogen fixation establishment until, *and only until*, such time as commercial industry assumes such proportions that it can be depended upon to supply our nitrogen requirement in case of war As it stands today, United States Nitrate Plant No. 2 can fix from the atmosphere the nitrogen required for the continuous supply of ammunition for an army of approximately 1,250,000 men.

Ordnance Progress During the Year

Extracts from the Annual Report of Major General C. C. Williams, Chief of Ordnance, recently submitted to the Secretary of War, for the fiscal year ended June 30, 1923

Emergency Reserves

I wish to emphasize the preponderating importance of adequate emergency reserves. When we consider the isolated position of the United States with respect to other great military countries, its highly developed and specialized industries and immense resources; it seems fairly certain that no power or combination of powers now in existence could successfully invade the United States after our manpower and our industry had been fully mobilized. The possible rate of mobilization will always be determined by the state of our reserves, since manpower can be mobilized much more rapidly than industry. *From this point of view, taking into account the present economic development of the world, it may be said that the next major war will be won or lost on the sufficiency of munitions reserves.*

At present we have a large stock of reserves left on hand from the World War. As time goes on, however, these stocks will be of less and less value, on account of obsolescence due to development of improved and more powerful types of matériel, and also, in the case of ammunition, due to a gradual shrinkage of our stocks through deterioration. The question of ammunition is very much more pressing than that of obsolescence of matériels.

A study is now being prepared to show the requirements of the Ordnance Department, in financial terms, year by year, under the assumption that adequate war reserves will be maintained, but that these reserves are to be kept at a minimum quantity.

Experimental and Development Work and Manufacture of New Materiel

Immediately after the approval of the Caliber Board program for the development of artillery and automotive matériel, the Department undertook the redesign of practically all of its matériel. On account of lack of funds during the past two years, the program has been finally contracted to cover reasonably well only infantry, pack, and divisional matériel, the smallest caliber of antiaircraft matériel, and one type of tank.

The Department now finds itself unable to carry out even the contracted program during the coming fiscal year, to an effective degree. New designs of matériel are ready for production of pilots, but funds are not available for their completion. This will delay development work on all present projects, and carry over beyond the fiscal year 1924, work which might, with ease, have been completed during that time, were funds available. At the same time, the Department has a considerable number of other suspended projects which have been partially completed or partly tested, and in which it is impossible to carry the test to conclusion and to correct mechanical defects.

The Department has now been working on the program for four years and can see no hopes of developing for the service and getting certain of the designs under the limited program, ready for production without substantial increase in the funds available. Work which could, with a larger organization, be undertaken in one year, is now requiring three years to complete.

Rifles

Eight thousand one hundred and nine service rifles were manufactured during the year. The model of 1922, caliber .22 gallery practice rifle has been approved for issue to the service; but funds are not now available to complete the number required for issue.

Machine Guns

Contracts have been placed for seventy caliber .50 machine guns, of which fifty are of the aircraft type. Requirements exist for one hundred and fifty additional caliber .50 aircraft machine guns for which no funds are available.

Corps Artillery

Manufacture of the pilot motor carriage for the 4.7-inch gun—155-mm. howitzer, is still in progress. The manufacture of the pilot corps tractor, model of 1921, has not been completed, although the vehicle has been partially assembled and given a short preliminary test. This model was designed to be tested as a complete track-laying unit with one set of equipment, and as a convertible wheel-track-laying unit with another set of equipment. Plans are being laid looking to the investigation of the suitability of commercial types of tractors for corps artillery missions. Lack of funds will probably prevent completion and service tests of pilot carriages for at least another year.

Fire Control

Study has been continued, and progress is being made, in connection with the development of instruments for seacoast, and antiaircraft fire-control. Work on antiaircraft fire-control equipment has been hampered by lack of funds needed to investigate foreign matériel, and to employ sufficient suitable personnel in the Ordnance Department.

Army Motor Carriages

The development of motor carriages has been greatly hampered by lack of sufficient personnel to analyze the results of tests, and to lay out new designs. This condition is due to the limited funds available, and may serve to delay for several years the completion of satisfactory types.

Tractors

The lack of sufficient funds seems to seriously delay the development of special tractors for strictly military purposes, and likewise to prevent the purchase and test of commercial tractors in sufficient number to determine the ones which can be procured in quantity and will most nearly fulfill the requirements.

Tanks

Proving ground and service tests of the two pilot models of medium tanks (Model of 1921 and Christie) progressed during the year.

It has not been possible to take full advantage of the results of tests on account of lack of sufficient personnel to lay out the new designs. The development program has

been correspondingly delayed and can not be brought to a successful conclusion for some time, unless larger appropriations are made for this purpose.

Supply and Maintenance of Materiel

During the past year the Ordnance Department carried out its functions in connection with the supply, inspection repair and maintenance of matériel as satisfactorily as the limited amount of funds available would permit. Storage conditions of ordnance matériél in storage at permanent ordnance establishments were materially improved and, in general, stocks at the corps area ordnance issuing establishments were maintained within satisfactory limits. Extreme shortage of transportation funds, however, precluded the possibility of replenishing local stocks to any considerable degree. This necessitated in many instances, less than carload shipments over long distances, a procedure manifestly uneconomical. Satisfactory progress was made during the year in the administration and training for their field duties of all Ordnance Companies.

Supply

The limited funds now available for this procurement of spare parts to be used in the maintenance of ordnance equipment are being utilized—first, to provide the parts needed for the army as now organized, and, second, to provide the reserve parts in accordance with the recent army appropriation act. In general, the Ordnance Department has been able to meet the needs of the army for the parts required to keep its equipment in proper serviceable condition.

The Ordnance Department must maintain, for the information of the War Department, a record of major items of ordnance equipment which are of a permanent character. To accomplish this a complete set of forms was recently approved and issued for reporting such items to the office of the Chief of Ordnance, where these reports are consolidated. This consolidation, besides showing the total of each item in existence, shows the total of each item which is in the possession of each of the several components of the Army of the United States, viz: Regular Army, National Guard, R. O. T. C., etc. These forms supersede and eliminate a number of similar reports formerly required to maintain a record of ordnance supplies.

Maintenance

Among the principal activities of the Ordnance Department during the year were the maintenance of matériel, both in the hands of troops and in storage; the procurement of spare parts; the overhaul of matériel turned in to store from the service; and the modification and alteration of matériel.

Salvage

The Ordnance Salvage Board is charged with the disposition of all surplus ordnance property acquired since April 6, 1917. It exercises supervision over the salvage activities at all ordnance establishments and over the district ordnance salvage boards.

Practically all surplus ordnance property has now been disposed of, with the exception of a small amount of inert ammunition components and a number of artillery vehicles which will shortly be offered for sale. The remaining stocks of surplus and unserviceable loaded ammunition were completely disposed of during the fiscal year by sale, transfer, destruction, or salvage. Practically all available surplus explosives were transferred to the Department of Agriculture, the bulk of the transfer being smokeless powder in an amount of 55,000,000 pounds.

With a view to assisting the Department of Agriculture in storing and conserving the powder transferred to it, the Ordnance Department suggested and effected the temporary transfer of the Tullytown Ordnance Reserve Depot to the Department of Agriculture, for use as a storage depot, and all the surplus named has now been consolidated at that point. Destruction has been confined to a relatively small amount of ammunition, principally pyrotechnics and trench warfare material, without salvage or sale value.

In round numbers, property of an original cost value of $188,000,000 was sold, and material valued at $42,000,000 was transferred to other branches of the Government. The greater part of the property transferred went to the Bureau of Public Roads of the Department of Agriculture.

Nitrate Plants

The steam power plant at Muscle Shoals was under lease to the Alabama Power Company; the rental received during the year for this plant was $231,949.28.

The Government extension of the Gorgas Plant, the latter belonging to the Alabama Power Company, situated on the Warrior River, was also under lease to the Alabama Power Company during the year, the rental received from this source was $153,939.22.

Expenditures by the Government for these three plants during the year, made from the ordnance appropriations "Repairs of Arsenals" and "Ordnance Service" amounted to $86,050.75. This leaves a net earning to the Government for the year of approximately $300,000.

Planning

One of the most important duties of the Ordnance Department is planning, in the sense that it is only by means of such planning that we can insure adequate supplies of the most up-to-date munitions for our troops in time of war. It is, of course, obvious that no matter how well our designs may be developed, even though they may be superior to those possessed by an enemy, they are of no avail unless the matériel represented is furnished the combatant troops in adequate quantities.

The ordnance district scheme has been more fully developed than at the time of my last report. The following districts are established and in operation:

Baltimore, Chief, Mr. Howard Bruce; Boston, Chief, Col. C. H. Tenney; Bridgeport, Chief, Col. B. A. Franklin; Chicago, Chief, Mr. E. A. Russell; Cincinnati, Chief, Col. C. L. Harrison; Cleveland, Chief, Col. Bascom Little; Detroit, Chief, Mr. H. A. O'Dell; New York, Chief, Brig.-Gen. John Ross Delafield; Philadelphia, Chief, Mr. J. C. Jones; Pittsburgh, Chief, Mr. R. M. Dravo; St. Louis, Chief, Mr. M. E. Singleton; San Francisco, Chief, Lt. Col. Bruce Cornwall.

There has been no change in the basic scheme of these districts. A large portion of our war requirements have been allocated to specific manufacturers for war production. The response from industry has been most gratifying. Almost without exception manufacturers and others have been glad to cooperate with the Department in working out its plan.

Ordnance Officers' Reserve Corps

On June 30, 1922, the number of Ordnance Reserve Officers was 2,403; on June 30, 1923, the total was 2,461, a net gain of 58. Each Reserve officer has been assigned specific duties in case of call to active service in an emergency. Units of the Reserve Officers' Training Corps are maintained at the Massachusetts Institute of Technology, Yale University, Cornell University, Georgia School of Technology, University of Wisconsin, University of Michigan, University of Cincinnati, and University of California. This is an increase of one unit, as compared with the preceding year.

The Synthetic Ammonia Process of Nitrogen Fixation

By

ALFRED T. LARSON

ALTHOUGH attempts to produce ammonia directly from its elements date back to 1807, the first quantative study of the synthesis of ammonia was probably not made until 1865. In that year Deville passed a nitrogen-hydrogen mixture through a heated porcelain tube with a water-cooled core (his so-called "hot-cold tube") and found that ammonia was produced in the neighborhood of 1300°C. The amounts formed, however, were very small.

A British patent granted to Clark in 1874 urged the advantages of certain contact agents or catalysts in bringing about the direct synthesis of ammonia, and described a process by means of which it was held ammonia could be produced directly from its elements. The patent evidently was an attempt to crystallize the ideas prevailing at that time. There is, however, no evidence that ammonia was ever actually produced by Clark's process.

The Fixed Nitrogen Research Laboratory, American University, Washington, D. C.

From his principle of mobile equilibrium which he first enunciated in 1884, Le Chatelier showed that in a reversible reaction involving a volume decrease such as the formation of ammonia from its elements, an increase in pressure results in an increase in the amount of ammonia produced. Since the reaction evolves the heat it also follows from this same principle that an increase in the temperature at which the reaction takes place decreases the equilibrium amount of ammonia produced.

By 1900 it had been shown that hydrogen and nitrogen would combine directly to form ammonia. It was recognized that the reaction was a slow reaction and attempts had been made to employ an accelerator or catalyst. It was known that the reaction was a reversible reaction in which the pressure and the temperature of the reacting gases played important roles. But even with this information available no one up to that time had ever produced any appreciable quantity of ammonia by the direct synthetic method.

In 1905 Haber published his first paper on the ammonia equilibrium. In this investigation he determined the maximum amount of ammonia which could be produced at 1000°C. and one atmosphere pressure. Two years later he published a second paper in which he determined these values down to 700°C. In 1908 he published his first work showing the effect of pressure. During 1914-1915 appeared a series of seven papers in which Haber described the results of a redetermination of the equilibrium percentages of NH_3 at 30 atmospheres pressure and temperatures down to 561°C. From his measurements Haber computed the equilibrium percentages of ammonia which would probably be obtained at pressures up to 200 atmospheres and temperatures as low as 200° C.

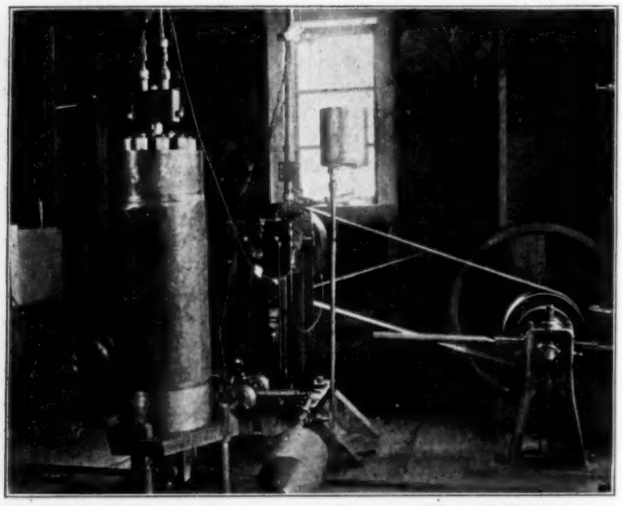
Haber's researches on the ammonia equilibrium may properly be considered the first great contribution to the synthetic ammonia industry. These experiments and the computations based thereon showed for the first time the maximum amount of ammonia which could be produced at any given temperature and pressure. The equilibrium data in itself, however, did not constitute any assurance that the process could ever become commercial; for the data might have been obtained by some indirect method, for example, by means of the Nernst heat theorem. Haber's real contribution lay rather in his study of catalyzers and a recognition of their characteristics. It was this knowledge which made possible the direct measurement of the equilibrium values down to temperatures as low as 561°C. It was this knowledge which in the final analysis made possible the establishment of the industry. It shall be the purpose of this article to indicate the limitations which ammonia catalysts heretofore known have placed upon the direct synthesis method and to describe the outstanding features of some of the more important developments which have been made in the commercial adaptation of this method of making ammonia.

Table I. Ammonia Equilibrium

	Haber Data Pressure atm. abs.				Claude Data Pressure atm. abs.			
Temp. °C.	1	30	100	200	400	600	800	1000
200	(15.3)	(67.6)	(80.6)	(85.8)				
300	(2.18)	(21.8)	(52.1)	(62.8)				
400	(0.44)	(10.7)	(25.1)	(36.3)	(45)	(58)	(70)	(78)
500	(0.129)	(3.62)	(10.4)	(17.6)	(26.4)	(36.0)	(44.3)	(50.0)
600	0.049	1.43	44.7	8.25	14.6	20.5	26.0	31.0
700	0.0223	0.66	2.14	4.11	7.7	11.4	14.5	18.0
800	0.0117	0.35	1.15	2.24	(3.6)	(5.0)	(7.5)	(10.5)
900	0.0069	0.21	0.68	1.34				
1000	0.0044	0.13	0.44	0.87				

Plain figures are interpolated or experimental results.
Figures in parentheses are extrapolated values.

In the technical manufacture of ammonia the important thing is not only the position of the ammonia equilibrium, but also the velocity with which that equilibrium is attained. Since the reaction velocity at any given temperature and pressure depends upon the activity of the catalyst, it follows that the lowest temperature at which the synthetic ammonia process can advantageously be operated depends upon the characteristics of the catalysts employed. Haber found that with the best catalysts then available the reaction became so slow in the neighborhood of 500° C. that operation below that temperature was not technically feasible. As the temperature is increased the reaction velocity, of course, increases very rapidly. Unfortunately, the equilibrium values begin to fall off rapidly as the temperature is increased, so that what is gained by an increase in reaction velocity is eventually lost by the unfavorable position of the equilibrium value. Haber set 700° C. as the limit above which he did not consider it practicable to operate the process. Between these limits, namely 500°-700° he found that operation could advantageously be carried out. So far as our present information goes all commercial installations in the world are today operating within this temperature range.



15,000-lb. Testing Apparatus, Fixed Nitrogen Research Laboratory

Table I shows that even under the most favorable conditions only a mere trace of ammonia can be obtained at ordinary pressure above 500° C. The temperature of the catalyst would probably have to be lowered to approximately 300° C. before the conversion would become high enough to give commercial yields. In this connection Clark's process, which was described in 1874 (British patent No. 4308) is of interest. Clark planned to operate at atmospheric pressure and provided for the passage of nitrogen and hydrogen in the ratio of 1:3 over a contact surface, the absorption of the ammonia formed, and the return of the uncombined gases to a holder from which they were again withdrawn and passed over the catalyst. This recirculation of the gas through the catalyst was continued until the nitrogen and hydrogen had been converted into ammonia. Lack of a suitable catalyst, of course, prevented Clark's process from ever becoming a commercial success.

In order to obtain any appreciable conversion with the catalysts now available, it is evident that the synthesis must be carried out under pressure. Table I indicates the extent to which the ammonia formation may be increased as the pressure of the gases is increased. The question naturally arises—what is the best pressure at which to operate? Haber has suggested that the higher the working pressure the more advantageously can the process be operated. Which means, operate the process at the highest pressure which present day engineering skill has developed. When the Germans built their great plants at Oppau and Merseberg this pressure was in the neighborhood of 200-250 atmospheres, and this is the pressure at which these plants were actually operated. If 1,000 atmospheres pressure had been as easily obtainable some such pressure as this would undoubtedly have been employed.

Whenever the operating conditions are such that the percentage of uncombined gases is high, it is evident that they cannot be discharged but must be returned to the catalyst for further action after the ammonia formed has been removed. Fortunately, the ammonia can be removed while the gas is under pressure and the uncombined gases again returned to the catalyst with the aid of a circulating pump. Fresh amounts of compressed nitrogen-hydrogen mixture may then be added to the circulating system as rapidly as ammonia is formed. This, in brief, is the process described by Haber for carrying out the direct synthesis of ammonia. Assuming that we have the gases purified and under pressure, the Haber process consists essentially of a catalyzer bomb within which the ammonia is formed, an ammonia scrubber, and a gas circulating pump. The similarity to Clark's process described above is very striking. If Clark had operated under pressure his process would have been practically the same as that described by Haber.

The first installation operating the Haber process was essentially an experimental plant built by the Germans at Ludwigschafen. During 1913 this plant fixed about 1,600 tons of nitrogen. Later two large installations were built, one at Oppau near Ludwigshafen, with a capacity of 100,000 tons of nitrogen per year, and another at Merseberg, with twice the capacity of the Oppau plant. At present Germany has facilities for producing approximately 300,000 tons of nitrogen a year by the direct synthesis method. These German plants operate at a pressure of 200-250 atmospheres, the temperature of the catalyst being maintained in the neighborhood of 600° C. The purity of the gases and their rate of flow through the system are such that the gases leaving the catalyst contain about 5 per cent of NH_3. The ammonia formed is removed by scrubbing the gases with pure water under pressure. Since the reaction in exothermal the process can be auto-thermal by passing the gases leaving the catalyzer and those entering through a heat interchanger. After the reaction is once started it is unnecessary to add any further heat to the catalyzer. In the German plants, the NH_3 is withdrawn in the form of a 25 per cent ammoniacal solution which is then sold as such or distilled to give gaseous NH_3.

In the United States two relatively small plants operating the direct synthetic ammonia process have been built. The first of these was constructed by the Government at Sheffield, Alabama (U. S. Nitrate Plant No. 1). Only one unit of 7½ tons per day, representing one-quarter the contemplated capacity of the plant was ever completely installed and operated. The other plant (18-20 tons per day) was built at Syracuse, New York, by the General Chemical Company. Both of these plants employ the cyclical process. The gases are compressed to about 100 atmospheres pressure and the ammonia is removed by cooling the gases to —30° to —40° C., where a large fraction of the ammonia separates out as a liquid and is withdrawn as such.

It is reported that a 30-ton per day direct synthetic ammonia plant is in operation in England. Although practically no definite information regarding this plant is avail-

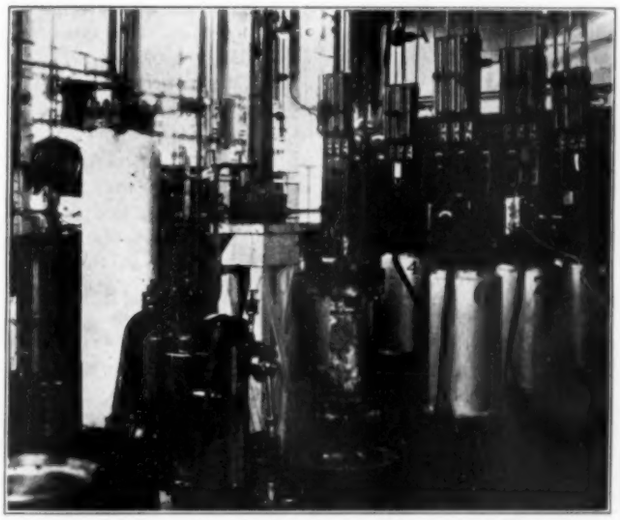
able, it is generally understood that the process is cyclical and that the conditions of operation are much the same as those described above for the German plans.

Aside from the mechanical difficulties encountered one of the principal drawbacks to the use of pressures higher than those employed in the German plants seems to have been the comparatively short life of the catalyzer. Operating at 200-250 atmospheres the German catalysts are said to require replacement only every five or six months. Claude, on the other hand, operating at 900-1000 atmospheres renews his catalyst about every ten days. It is generally conceded that the rapid decrease in longevity of the catalyst is due to the greater amount of heat produced when the reaction is carried out at the higher pressure. Since five to eight times the amount of ammonia is produced at the higher pressure, of course five to eight times as much heat is produced. Unless the heat is quickly dissipated it is conceivable that some portions of the catalyzer may be heated to very high temperatures. Luigi Casale of Rome, Italy, has suggested the operation of the cyclical process in such a way that close regulation of the temperature of the catalyst is easily accomplished. In U. S. patent No. 1,447,123, he described his process as a "cyclic process of synthetically producing ammonia which consists in initiating the process by first subjecting nitrogen and hydrogen gases to the action of a catalyzer and subsequently carrying out the regular cycles by utilizing some of the ammonia thereby formed together with the uncombined amounts of nitrogen and hydrogen in the process of producing additional amounts of ammonia; the last-mentioned regular cycles being carried out at a pressure of several hundred atmospheres and at a high temperature and the proportion of ammonia associated with the nitrogen and hydrogen being in the vicinity of 5 per cent at the beginning of each regular cycle."

In Claim 2, Casale further describes his process as "A self-regulating method of catalysis for the production of ammonia which consists in bringing into the presence of a given catalyzing agent at a temperature compatible therewith only such admixtures of hydrogen and nitrogen as contain about 5 per cent of ammonia gas and in performing said operation under a high pressure."

Casale's method as actually employed is essentially a cyclical process operating at 600-700 atmospheric pressure. The ammonia is liquified by cooling the gas mixture leaving the reaction bomb to about 20° C. The temperature of the cooler fixes the amount of ammonia which is returned to the catalyst bomb which in turn determines the amount of ammonia which can then be formed. The amount of ammonia formed determines, of course, the amount of heat produced. Therefore by controlling the temperature of the ammonia removal system one automatically controls the temperature of the reaction bomb.

In so far as the life of the catalyst is concerned the chief advantage gained by returning a part of the ammonia to the reaction bomb lies in the slowing up of the reaction. If the conditions of operation are such that very nearly the equilibrium percentage of NH_3 is being formed, it can be shown that about 50 per cent of the ammonia is formed in the first 2 per cent of the catalyst bed. The initial formation of ammonia, comparatively speaking, is very rapid. This means, of course, that the temperature of this relatively small layer of catalyst may be increased considerably. It is conceivable that there might follow then a progressive decrease in the activity of the catalyst as this narrow layer moves in the direction of the gas flow. Casale proposes to slow up the reaction by leaving in the recirculated gas a comparatively large fraction of the ammonia formed. So far as the effectiveness of this method is concerned there certainly can be no question but that this does slow up the reaction. If the deterioration of the catalyst is due to local heating, this method of control ought to result in an increase in the life of the catalyst. With this method of control Casale finds that he is able to obtain satisfactory action of the catalyst for a period of about forty days. The output of a given installation could, of course, be increased about 25-30 per cent if practically all the ammonia were removed from the circulating system. It would be of interest therefore to know just how much the life of the catalyst has been extended by allowing a considerable portion of the ammonia to remain.



Compressors in the Catalyst Testing Plant, Fixed Nitrogen Research Laboratory

The first application of the Casale process was a one-quarter ton experimental plant built at Terni, Italy, in 1920. Later a one-ton plant was built at the same place and after being operated for about a year was installed in France for the French Aluminum Company. A 7½ metric ton plant was then built at Terni and another at Nero Montore, Italy. Plants have also been installed at Robeoka, Japan, and at Labinanago, Spain. A 7½ metric ton plant is also being built at Niagara Falls which will probably be ready for operation about January, 1924.

In the cyclical process just described it is evident that when the percentage conversion is relatively low the reacting gas mixture must be passed several times through the catalyzer before it is very largely converted to ammonia. For example, if the net conversion is 10 per cent during each passage through the catalyst there would still be 12-13 per cent of uncombined gas remaining after the cycle had been repeated twenty times. The cycle need be repeated but three times, however, if the net conversion can be increased to 50 per cent, while two passages through the catalyst would be sufficient if the net conversion reached 65 per cent.

Claude has suggested that when very high conversions are obtainable it is preferable to pass the compressed gases successively through catalyzers arranged in series, the number of catalyzers being determined, of course, by the percentage conversion possible within each member of the series. Such an arrangement avoids the mechanical difficulties of the circulatory process and has the further advantage that the impurities and inert gases are not cumulative but are expelled continuously at the exit of the last reaction bomb of the series.

An examination of Table I shows that there may be two ways in which the percentage ammonia can be increased—(1) the temperature of the reaction may be lowered, or (2) the pressure may be increased. Claude found, just as Haber before him, that the synthetic ammonia process could not be operated commercially at temperatures below 500° C. no matter what pressure was employed. The only alternative then was to increase greatly the pressure, which was what Claude did. At 1,000 atmospheres pressure he found that 40-50 per cent of the gas could be converted into ammonia on a single passage through the catalyst. Instead of circulating the gas he simply placed three or four catalyzer tubes in series. With this arrangement Claude claims to have been able to effect the synthesis operation with much greater ease than is possible when a cyclical process is employed. The Claude process as actually operated consists of two bombs in parallel, followed by three bombs placed in series. The bombs operate at a pressure of 900-1000 atmospheres. The ammonia produced within each bomb is liquefied by passing the gas through coils immersed in cold water. Since this method of cooling does not completely remove the ammonia formed within each unit, each bomb except the first in the series (actually two in parallel) operates on a gas mixture containing a relatively high percentage of ammonia. As discussed above in connection with the Casale process, the presence of this ammonia in the gas ought to show up the reaction, and as a consequence give a relatively greater life to the catalyst. The writer has no knowledge of the longevity of the catalyst in the first unit which operates on ammonia-free gas as compared with that of the remaining members of the series. It is known, however, that in actual practice the catalyst in the first unit is not replaced until the other catalysts have been renewed.

There are at least three installations which are operating the Claude process for making synthetic ammonia. A five-ton plant is in operation at Montereau, France, and a three-ton plant at Bethune, France. A third plant having a daily capacity of five tons is in operation in Spain and it is reported that a similar plant is being installed in Japan.

The study of ammonia catalysts which has been made at the Fixed Nitrogen Research Laboratory shows that it is possible to operate the synthetic ammonia process at lower temperatures than those heretofore considered feasible. These experiments show that there is nothing in the nature of the process or the properties of the gases which prevents low temperature operation, but that the limiting factor in the past has been the activity of the catalyst. For example, it has been found that 60-65 per cent conversion of the nitrogen-hydrogen gas mixture is quite possible when the pressure of the gas is 1,000 atmospheres. Even at a pressure as low as 600 atmospheres 40-45 per cent conversion has been obtained at temperatures below 500° C.; while at 300 atmospheres the process should be operated commercially to give 30-35 per cent conversion.

It is evident that it is not necessary to subject the gas to the very high pressures employed by Claude in order to operate a series of bombs, or if Claude's high pressures be employed it is now possible to decrease appreciably the number of units in the series. Even now a series arrangement containing but two bombs is possible. It is not too much to hope that catalysts will be developed in the future which will be so reactive that the compressed gas will be 90-95 per cent converted into ammonia the first time it passes through the reaction bomb.

The very reactive catalysts which are being developed can, of course, advantageously be employed in the cyclical process. The most interesting possibility here probably lies in the lowering of the operating pressures to those which are now becoming common in high pressure steam practice. Even today catalysts are available which may make operation commercially feasible at pressures as low as 500 pounds.

The National Screw Thread Commission

The National Screw Thread Commission was authorized by Congress in 1918 (H. R. 10852), and since then its life has been three times extended. First, for one year beyond the original six months; then for two years additional; and lastly for five years additional. Its term now expires March 24, 1927.

The Commission is composed of nine members. The Chairman of the Commission is the Director of the Bureau of Standards. There are two representatives of the Army appointed by the Secretary of War; two representatives of the Navy appointed by the Secretary of the Navy, and four appointed by the Secretary of Commerce, two of whom are nominated by the American Society of Mechanical Engineers, and two by the Society of Automotive Engineers. The present personnel of the Commission is G. K. Burgess, Chairman; Lt. Col. E. C. Peck, and Major J. O. Johnson, representing the Army; Commander J. N. Ferguson and Commander M. A. Libby, representing the Navy; F. O. Wells and R. E. Flanders, representing the A. S. M. E.; Earl Buckingham and George S. Case, representing the S. A. E.

The authorization and appointment of the Commission was the outgrowth of experiences during the World War in the production of munitions and gages on an interchangeable basis. The Army Ordnance Department, the National Engineering Societies and the Bureau of Standards all take an active part in urging the importance of such a centralized body to bring about the national standardization of screw threads. The original bill authorizing appointment of a Commission, and subsequent bills extending its life, were all introduced and ably handled in Congress by Representative John Q. Tilson of Connecticut.

The original Commission under Chairmanship of Dr. W. S. Stratton, in September, 1918, began active work on the standardization of screw threads. Public hearings were held in Washington, New York, Detroit, Cleveland, and Dayton, in order to obtain from manufacturers and users of screw threads first-hand information as to American screw-thread practices. After extensive study of conditions and practices the Commission drew up a progress report, which was published under date of January 4, 1921, and which contained complete information as to thread series, diameters, tolerances, allowances, and a classification of fits for all ordinary threaded work except stud fits. This report has now been in use for nearly three years and has been widely accepted in the industries. It is now undergoing a revision and with minor changes will in all probability be adopted by the Federal Specification Board.

The Commission holds meetings once every month. The various industries interested in the subjects before the Commission at these meetings are notified and invited to attend giving their experiences and reasons for the adoption of new standards or the retention of old. It may be readily seen that the Commission, by this method, does not tend to upset or disturb, to any great extent conditions unless they are such as to make drastic measures necessary.

Benzol and Toluol for the Next War

By

FRED H. WAGNER

THESE two products will be considered together in this article, since toluol is a homologue of benzol, and its recovery is simultaneous with that of benzol. Both benzol and toluol are products of the destructive distillation of coal, as well as of the manufacture of carburetted water gas, consequently, besides the amount of these two important compounds produced by the operators of by-product coke ovens, the Ordnance Department will have to look to the producers of city gas for the vast supply of these products in case of future emergencies.

As a rule, city gas plants do not recover these oils from the gas (a small amount is recovered from the distillation of the tars produced) but, in case of emergency, the amount regularly produced by the by-product coke ovens will have to be augmented by the installation of the necessary apparatus in the gas plants, and this can be readily done, it being estimated that such plants as manufacture not less than 100,000,000 cubic feet of city gas a year can be made to supply a possible 604,000 gallons (4,385,500 lbs.) of toluol and about 1,542,000 gallons (11,352,000 lbs.) of benzol per month, providing conditions, as will be explained later, will permit of removing this amount of oil from the gas without added compensation.

Characteristics

The names benzol, toluol, xylol and naphtha are those usually applied to the articles of commerce, but the chemical names applied to designate the pure compounds are benzene, toluene, xylene, cumene, etc., the characteristics of which are:

	Benzene	Toluene	M. Xylene
Chemical formula	C_6H_6	$C_6H_5.CH_3$	$C_6H_4.(CH_3)_2$
Boiling Point at 760mm, 29.92" bar.	80.4 deg.C	110.4 deg.C	139.2 deg.C
Melting Point	+5.4 deg.C	—92.4 deg.C	—54.8 deg.C
Specific Gravity at 15.5 deg.C.	0.884	0.8714	0.8697

The naphtha is a mixture of several compounds, such as xylene, cumene, etc., and it has no designated chemical name.

These compounds are members of the benzene, or aromatic, group and, when pure, they are colorless and possess a rather sweet odor, while their refractive index is high. The usual commercial product is commonly known as "C. P." (chemically pure), and this compound is expected to boil or distil within 2 deg. C. In case of benzene the "C. P." should have a specific gravity of between 0.883 and 0.885 at 15.5 deg. C., and it should be entirely free from olefines and contain but slight traces of sulphur compounds. In the case of toluene, the specific gravity of "C. P." is between 0.869 and 0.871, and it must be entirely free from olefines and contain not more than 0.5 per cent of paraffins. The Ordnance Department has definite specifications for both benzene and toluene to be used in the manufacture of explosives, and these specifications will be mentioned later.

Besides this "C. P." article, there are a number of other commercial grades of benzene known as 100, 90 and 50 per cent benzene; these designations are, however, somewhat misleading, as they do not indicate that the benzene contains 100, 90 or 50 per cent pure benzene; they are meant to designate the fact that under certain conditions and at 100° C., the above percentages by volume will distil over. Commercial toluol, usually known as 90 per cent toluol, is a mixture composed mainly of toluol, 90 per cent of which will distil at 120° C. and not more than 5 per cent at 100° C.

Benzol is the base for the manufacture of phenol, while toluol is the base for the manufacture of trinitrotoluol, TNT., in which case the toluol is nitrated with a mixture of sulphuric acid and nitric acid. In intensity of explosion, TNT. ranks below picric acid, which latter is derived from phenol, but as against this it is much safer to handle and transport because it does not, as is the case with picric acid, react directly with the metals to form picrates, the latter being very sensitive to shocks.

It may be observed that as the molecule of TNT. contains insufficient oxygen for the complete combustion of the carbon atoms, it will produce smoke on being burned or exploded, but this property may be overcome by mixing it with some nitrate, preferably ammonium or lead nitrate.

Content and Composition of Light Oils in Gases

The amount of benzol and toluol produced in any of the various processes of gas manufacture is not a definitely known quantity, since the product will vary with the character of the raw materials used and upon the conditions governing the operation. Average figures can be used for an estimate, however, and those given below probably approximate the real values as closely as is possible.

Horizontal retort gas, per 2,000 lbs. of coal	3.0 gallons
By-product coke oven gas, per 2,000 lbs. of coal	2.6 gallons
Carburetted water gas, 3.6 gallons of oil per 1,000 cu. ft. of gas	0.36 gallons

The composition of these crude light oils may be approximated as follows:

	Benzol	Toluol	Solvent naphtha, naphthalene, wash oil, etc.
Horizontal retort coal gas	38 per cent	16 per cent	46 per cent
By-product coke oven gas	55 per cent	14 per cent	31 per cent
Carburetted water gas	42 per cent	25 per cent	33 per cent

The following will serve as a concrete example of what is usually secured in a by-product coke oven plant:

Light Runnings (benzol and carbon bisulphide)	1.00 per cent
Pure Benzol	57.00 per cent
Pure Toluol	14.50 per cent
No. 1 Refined Solvent Naphtha	4.50 per cent
No. 2 Crude Heavy Solvent Naphtha	1.50 per cent
Crude Naphthalene by weight	0.40 per cent
Wash Oil	12.00 per cent

The yield in pure products will probably be of the following order:

	Benzol gallons	Toluol gallons
Horizontal retort gas, per 1,000 cu. ft	0.115	0.045
By-product coke oven gas, 1,000 cu. ft	0.143	0.036
Carburetted water gas, per 1,000 cu. ft	0.15	0.09

This tabulation shows that carburetted water gas produces twice as much toluol as does retort gas, and 2.5 times as much as does coke oven gas, while in the case of benzol the carburetted water gas is about on a par with coke oven gas, but somewhat above retort gas, and as the ratio between water gas and coal gas manufacture in the United States is about 3 to 1, it will be readily seen that the former will be called upon to furnish the major portion of these important hydrocarbons in case of national emergency.

Besides the above mentioned hydrocarbons, the light oils contain 2 per cent or less of paraffins, and some carbon bisulphide.

Principles of Recovery

The light oils, as mentioned above, consist of benzol, toluol, xylol, etc., and these compounds exist in the gas in the form of condensible vapors which are associated with other hydrocarbons of the olefine and paraffin series, the latter possessing many physical properties very similar to those of the former. The separation of some of these compounds by commercial methods is almost an impossibility, and this is especially true in the case of the paraffins, consequently it is of the utmost importance to control the gas-making conditions so as to have as little of these substances in the light oils as is possible, since the presence of more than 2 per cent of paraffin compounds in the toluol makes the latter unfit for the manufacture of explosives.

This condition requires the exercise of the utmost care as regards operating temperatures and other conditions existent during the gas-making period, as well as in the selection of suitable raw materials. In the case of light oil recovery from carburetted water gas, temperature conditions, rate of oil injection, spacing of checker bricks in the carburettor and superheater, cleanliness of the checker bricks, etc., all have an important bearing on the results, and dirty checker brick especially influences the high paraffin content in the toluol produced.

Careful technical control of the operations is therefore necessary, and too much attention cannot be paid to the conditions of manufacture if a proper grade of oil is to be produced.

Process of Operation: Stage I. Absorption

The recovery of the light oils is accomplished by bringing the rich gas into intimate contact with an oil which is capable of dissolving and absorbing the light oil vapors contained in the gas. This process of absorption is practiced in quite a variety of different apparatus, but those most universally used are the grid-packed tower and the vertical rotary absorber (see Fig. 1, page 157). No matter what the character of the apparatus, its function is to bring an adequate amount of absorbing oil, at a sufficiently low temperature, in contact with the gas having a still lower temperature, and it is usual to employ an absorbing oil at 30° C. with a gas at 25° C. At a gas temperature of 25° C., a suitable oil at not more than 30° C. will absorb as high as 98 per cent of the light oils in the gas; at a gas temperature above 35° C. the proportion of light oils absorbed diminishes rapidly, until at 50° C. the absorption is only about 65 per cent. The absorbing oil should, however, be slightly warmer than the gas in order that no condensation of water from the gas into the oil may take place, as the presence of this water causes a great deal of trouble in the subsequent recovery operations.

The amount of absorbent oil circulated will, of course, depend upon the volume of oil vapors present in the gas, the temperature of both oil and gas, the volume of gas to be treated, and the character of absorbent oil employed. As a general statement, however, it may be said that from 10 to 12 gallons of absorbent oil per 1,000 cubic feet of gas treated is an average figure.

The oil commonly employed in this service is a petroleum distillate which, from its color, is called "straw oil"; in some cases creosote oil, obtained from the distillation of coal tar, is also used, but in any case the absorbent should meet the following specifications:

Beaume gravity	34 to 36 deg.
Initial boiling point	260 deg. C.
Viscosity at 38 deg. C.	70 seconds
Flash point	135 deg. C.
Pour test not to exceed	1.1 deg. C.
Emulsification test	90 per cent in 10 minutes
Wash test	After washing with 2.5 times its volume of H_2SO_4, and after the oil has been vigorously agitated with the acid for 5 minutes, the oil shall not lose more than 10 per cent by volume after being allowed to stand for 2 hours.

The grid-packed absorber is a cylindrical vessel from 45 to 70 feet high, the diameter usually being from 1/5 to 1/6 the height, packed with wooden grids or hurdles laid in successive layers, space being provided at the bottom for the proper distribution of the gas, and at the top for the proper distribution of the absorbent oil, the latter being injected through a series of distributing sprays. Grids made of 5½" by ⅜" boards spaced ¾" apart, will give about 20 square feet of wetted surface per cubic foot of volume; the gas entering at the bottom passes upwards between the interstices in the grids and thus comes in contact with the wet surface of the latter. The dimensions of this absorber are dependent upon the volume of gas to be treated, the usual practice being to allow 30 cubic feet of scrubber volume (including the gas space at top and bottom) per 1,000 cubic feet of gas to be treated per hour.

The contact between the gas and the absorbent is, however, much more intimate in the vertical rotary absorber, thus permitting of a higher degree of saturation of the absorbent oil with a consequent reduction in the dimensions of the subsequent recovery apparatus due to the lesser amount of oil to be handled by the latter for the same amount of light oils recovered. The oil in the vertical rotary scrubber is broken up in each section into minute globules, about 0.01 inch in diameter, and a cubic foot of oil thus atomized will present 7,200 square feet of surface past which the gas must travel; it is therefore readily seen how much more intimate the contact between the same amount of oil is in the vertical rotary absorber as compared with the problematical skin contact in the grid type absorber.

Stage II. Stripping the Rich Oil

By reference to the diagram it will be seen that when the gas leaves the absorber, it passes through a "catch scrubber" for the removal of any entrained absorbent oil, and the saturated or "benzolized" oil then passes into a pump tank. From this pump tank the benzolized oil is pumped through a tubular section in the dephlegmator, where its temperature is slightly increased, and then through an oil-to-oil heat interchanger, finally passing through steam heaters into the continuous stripping still, entering about half way up the height of this still with a temperature of about 120 deg. C. The bottom of this stripping still is provided with a chamber into which live steam is injected to the body of the oil.

When the hot benzolized oil is pumped into this stripping still, the lower boiling fractions of the light oils are vaporized and pass upwards through the column, while the absorbent oil, carrying the unvaporized light oil, flows

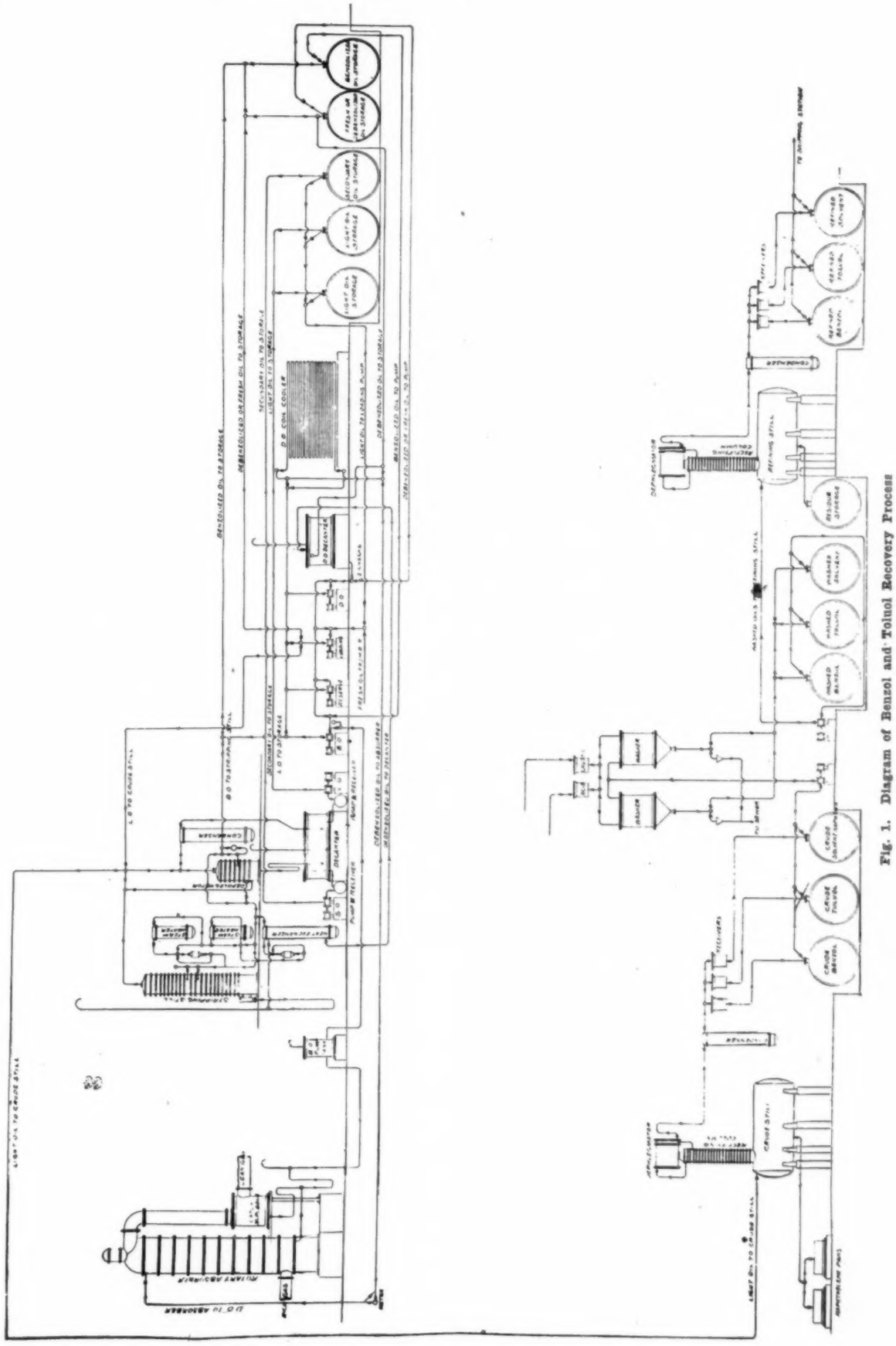


Fig. 1. Diagram of Benzol and Toluol Recovery Process

downward through the column to the bottom chamber, where it meets the live steam introduced at this point, and its temperature is increased to a point where all of the light oils are distilled off.

Under the law of partial pressures, if live steam is admitted to the hot oil in the bottom of the column, the temperature at which the light oil will be driven off is reduced; for instance, xylol, which is the main constituent of solvent naphtha, and which boils at a temperature of 141° C., will boil, when live steam is admitted, at a temperature of 91.5° C. By this means the total light oil is driven off and upwards through the column. The column itself consists of a number of cast-iron sections imposed one above the other, the bottom of each section being provided with a number of hooded ports, the hood or bell of each port being sealed in the liquid contained on each bottom, and which seal must be broken through as the liberated vapors pass upwards, these vapors being thus absorbed by the liquid.

Some of the vapors will become fluid and give up their heat to this body of liquid; this will in turn cause vaporization of the lighter portions of the liquid, and these vapors will pass on up to the next hooded section, and so on until the top is reached. The vapors leaving the stripping still enter the bottom of the dephlegmator, partially heating the incoming oil in the tubular section by giving up a portion of its heat.

The temperature of this dephlegmator is thermostatically controlled so as to permit the light oil to go forward as a vapor, but any water, wash oil or absorbent, or heavier material will be condensed and will flow away from the bottom as liquid, or secondary oil, to a condenser or decanter, and thence to storage. Here it may be collected and the material again be pumped with the benzolized oil from the absorber to the stripping still, or it may be disposed of otherwise.

The vapors issuing from the dephlegmator pass into a condenser and the light oils there condensed then pass through a decanter, for the removal of any water, after which they are sent on to storage.

This is a continuous operation, and the efficiency of the recovered absorbent oil for further service in the absorber will depend on the degree of separation of the light oil from the absorbent oil, or upon the efficiency of the stripping still. If the absorbent is sent back to the absorber without a thorough separation from the light oil, its efficiency for further absorbing the light oil will be materially reduced. The efficiency of this separation in the stripping still will depend upon, first, the temperature at which the oil is admitted into the column, which temperature should not be allowed in any case to go below 105° C., and secondly, on the proper design of the still. No general rule can be given for the dimensions of this still, as they will depend upon individual circumstances, and each one must be designed to suit existing conditions. As an indication of what is required, however, the following will serve as an example:

150 gallons of light oil per hour	18	lower sections, 42″ diam.
	8	upper sections, 28″ diam.
100 gallons of light oil per hour	14	lower sections, 42″ diam.
	6	upper sections, 28″ diam.
65 gallons of light oil per hour	16	lower sections, 28″ diam.
	6	upper sections, 28″ diam.
40 gallons of light oil per hour	15	lower sections, 28″ diam.
	5	upper sections, 28″ diam.

If a dephlegmator is used of the character shown in the diagram, it should have the same cross-sectional area as that of the still, and should consist of six hooded sections, but the area of the ports under the hoods should be only 33 per cent of the area in the still.

If a dephlegmator of the type shown on the crude and refined stills on the diagram is used, or one where the reflux is sent directly back into the rectifying column, it should have a cooling surface equivalent to 4 square feet per gallon of light oil per hour leaving the still.

The condenser should have a cooling surface of 5 square feet per gallon of light oil, while the heat exchanger should have a surface of 6 square feet, and the steam heaters 12 square feet per gallon of light oil recovered per hour.

After passing through the oil-to-oil heat interchanger, where its temperature is somewhat reduced, the debenzolized absorbent oil is sent into a decanter, and from there through a pipe cooler (cooled by water sprays), and thence to storage, after which it is ready to again go forward to the absorber and repeat this cycle.

The result of these first and second stages of operation is the separation and collection in liquid form of the light oils from the absorbent oil, and the return of the debenzolized absorbent oil to the absorber.

There is extracted with the oils from the gas a jelly-like substance which will remain with the wash oil and which, if not removed, will cause the oil to become so heavy as to make it unfit for use. This material is known as cumarone. It is advisable therefore to provide a tank, water cooled and open to the atmosphere, into which a certain portion of the wash oil can be run each day to allow this cumarone and any naphthalene to settle. The cleared oil can be drawn from the top of this tank and returned to the debenzolized oil storage tank, the cumarone being then scraped out of the tank and discarded.

Stage III. Crude Fractionation

This consists in the separation of the benzol, toluol, and solvent naphtha fractions into crude products, and this separation is accomplished in a tank still as shown in the diagram. The still is provided with a fractionating column, and above this column is a water-cooled condenser or dephlegmator. The still is heated by steam contained in steam coils, and steam is also admitted directly into the body of the oil, this operation being an intermittent one.

After the still has received its charge of light oil, the indirect steam is turned on and the temperature at the vapor outlet of the dephlegmator at the top of the column is so regulated that the benzol fraction is liberated from the oil and passes out of the dephlegmator as a vapor. The temperature of the dephlegmator is then allowed to increase, and the toluol fraction is driven off, during the latter portion of which period, unless steam of unusually high temperature is available, live steam is also introduced into the body of the oil.

If it is desired to separate the solvent naphtha from the heavy naphtha left in the still, and from small quantities of wash oil which may have been carried over, live steam is continuously admitted into the body of the oil through a perforated pipe running along the bottom of the still; by this means the solvent naphtha will be driven off rapidly. The residue is then run out into the cooling pans where naphthalene settles out.

The different fractions are condensed in a tubular condenser, any remaining water is removed in a decanter, and the benzol fraction is run into the crude benzol storage tank, the toluol into the crude toluol storage tank, and the solvent naphtha into its crude storage tank.

The benzol fraction thus obtained should contain about 85 per cent pure benzol and olefines, the balance being some toluol and solvent naphtha. For this fraction the dephlegmator is kept at a temperature of about 80° C.

The toluol fraction will contain 60 to 80 per cent toluol, the balance being a little benzol, olefines and solvent

naphtha. For this fraction the dephlegmator is kept at a temperature of about 110° C.

The steam pressure, as shown by a gauge in the still house, should never be allowed to drop below 100 pounds, and this pressure should be constantly maintained by means of regulating valves, while the water supplied to the dephlegmator and condenser should also be uniform in pressure and fed at a uniform rate.

As regards the dimensions of this apparatus, the still body is usually made to take a charge of about 6,000 gallons, with a vapor space of another 1,000 gallons, making the body have a cubic capacity to take 7,000 gallons of liquid; it is usual to provide from 6 to 6.5 square feet of surface in the heating element per 100 gallons of charge, or a still body which would take a 6,000-gallon charge should be provided with say $6 \times 60 = 360$ or $6.5 \times 60 = 390$ square feet of heating surface. The rectifying column would consist of 22 plates or sections 42 inches in diameter; the dephlegmator should have a cooling surface of 6.5 square feet per 100 gallons of charge, and the condenser should be provided with the same surface, providing the charge is to be distilled off in 16 to 18 hours.

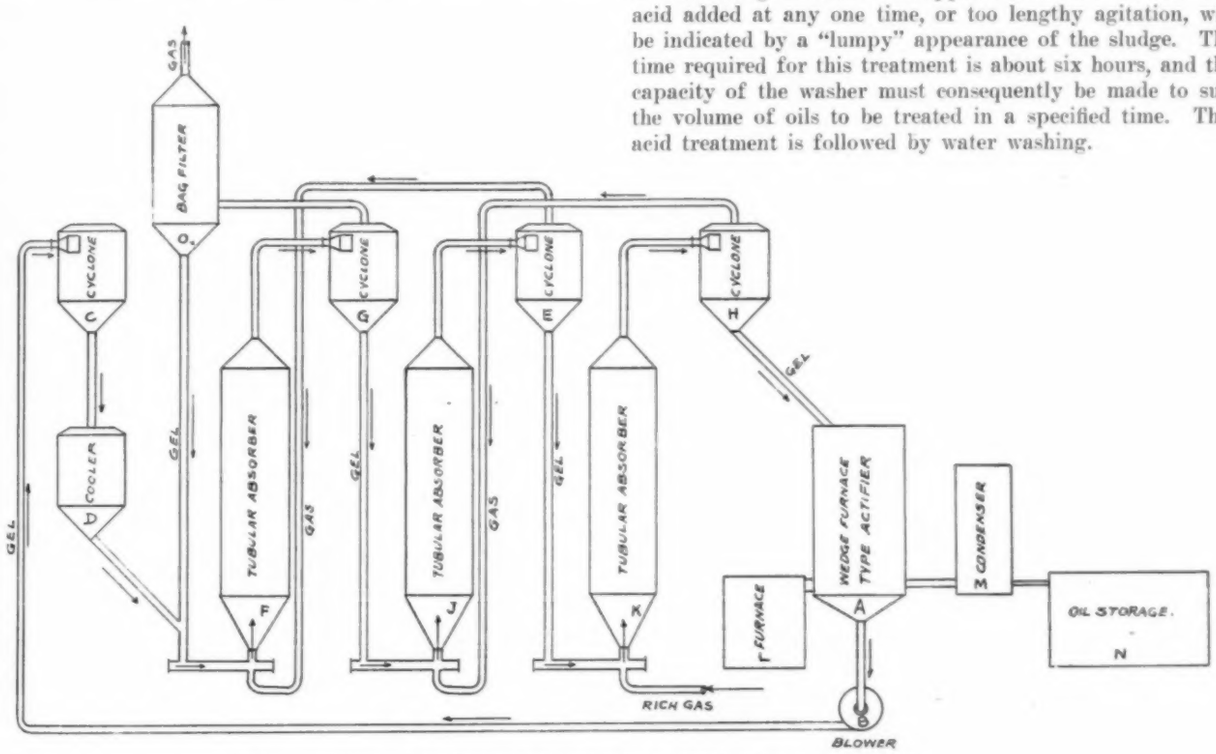


Fig. 2. Diagram of Continuous Absorption Plant Using Silica Gel Absorbent

Stage IV. Washing

This stage consists in treating the crude fractions with sulphuric acid for the purpose of separating the olefines from the recovered benzol, toluol, etc., and then with caustic soda solution for neutralizing any of the acid not in combination.

The oils at this stage are light yellow in color, and they are pumped into an agitator or washer which consists of a lead-lined vessel with cone bottom erected on an elevation above the floor. It is equipped with means for agitating the oil in order to secure a thorough mixing of the oil with the washing solution. When pure fractions are the objective, as is the case in this instance, it is usual practice to wash the benzol and toluol together, because toluol alone is washed with great difficulty.

The sulphuric acid is of about 66° Beaumé gravity, and this is added to the oil in small quantities; the mixture is agitated and then allowed to settle, after which the sulphonated olefines are drawn off with any excess acid from the bottom of the washer. More acid is added, again followed by agitation, and the sulphonated mixture is again drawn off after settling. This operation is repeated four or five times, and the olefines present are each time converted into an acid sludge that has the appearance of tar. Too much acid added at any one time, or too lengthy agitation, will be indicated by a "lumpy" appearance of the sludge. The time required for this treatment is about six hours, and the capacity of the washer must consequently be made to suit the volume of oils to be treated in a specified time. This acid treatment is followed by water washing.

After the olefines have thus been removed, and which can be determined by testing a sample with additional acid, a solution of caustic soda is run into the washer to neutralize any remaining acid; after this has been thoroughly mixed by agitation, the mixture is allowed to stand quiescent in the washer until all of the caustic soda solution, some of which will have been converted into sodium sulphate, settles to the bottom. This is then drawn off and the oils are again subjected to water washing.

The acid sludge may be run to waste, or it may be stored for future recovery of its acid contents.

The operation of washing must be very carefully performed, and this is especially true if the toluol is to be treated separately, and care must also be taken to use the sulphuric acid in such strength and quantities as not to destroy the toluol, but only to remove the olefines. Practice shows that in the treatment with sulphuric acid, a portion of the olefines contained in the toluol as sulphonated bodies always remains in suspension in the oil, or that this portion will not be precipitated or affected by the caustic soda; it travels onward with the toluol, and as soon as the oil is heated in further treatment, these sulphonated bodies are again decomposed with the evolution of sulphuric acid, the latter severely attacking the subsequent dephlegmator or condenser, unless precautions are taken to avoid this contingency.

Stage V. Refining

In this stage the washed fractions are pumped into an indirect steam heated still, of similar construction to that specified for the crude still, but on which the rectifying column consists of some 32 plates or sections. The dephlegmator at the top of this column is fitted with a thermostat in order that the temperaure can be absolutely controlled and the distillation carefully watched.

The fractions issuing from this still are, of course, treated separately, and in distilling benzol the temperature of the dephlegmator is so adjusted as to allow only the pure benzol to go forward as a vapor, condensing any toluol, etc., that may have worked up through the rectifying column, and which condensed material drops back into the still and is added to the next, or toluol, fraction, the latter being treated in the same manner as described for benzol, the temperature of the dephlegmator being of course increased to permit pure toluol to come over.

In the case of toluol recovered from carburetted water gas, the washed toluol is pumped into a tank still, fitted with an indirect steam heating element, but this still is not provided with a rectifying column as described above; the vapors from the still pass directly into and through the condenser, the liquid from the latter passing upward through a tank containing a caustic soda solution, and from this tank or washer the toluol flows direct into the refined toluol storage tank. This procedure is, of course, only followed when pure benzol is not to be recovered through the same still; if the latter is the case, the still will have to be provided with a rectifying column and dephlegmator.

Due to the coming over of some sulphonated olefines with the toluol fraction, and the consequent evolution of the contained sulphuric acid on being subjected to heat, the pipe leading the vapors from the still (in the case of carburetted water gas toluol) to the condensing coil, the condensing coil itself, and the outlet to the caustic soda washer should be made of lead. This will not, however, be necessary in the refining of toluol coming from coal gas.

All of these operations must be subject to careful technical control if efficient results and high quality of products are to be secured.

Continuous Dry Absorbent Process

The proposal has recently been made to remove the benzols from gas by means of dry absorbents, such as activated charcoal, silica gel, ferric hydroxide gel, and other base exchange silicates.

The activated charcoal is made by first destructively distilling the original carbonaceous matter in the presence, or in the absence, of such addition agents as zinc chloride, calcium chloride, phosphoric acid, etc., and this carbon product is then activated by a mild oxidation through the application of steam, carbon dioxide, oxygen-nitrogen mixtures, etc.

Silica gel is prepared by acidifying sodium silicate solution at a definite temperature and degree of concentration; the sodium chloride formed is then washed out, and the gel is dried at a relatively low temperature to a hard, glassy quartz-like mass. This gel is very porous owing to innumerable infinitesimally small capillaries, so small that they cannot be measured.

Base exchanging silicates, possessing high absorptive qualities, may be prepared by reaction between definite concentrations of sodium silicate and sodium aluminate solutions; all of these solid absorbents are protected by patent rights. The gels are less expensive to produce than is activated charcoal, and as they are at least equally as efficient as the latter, they will probably find more favor in practical application; besides this, they are also of a much greater density than activated charcoal, and consequently, for a given duty, silica gel should require a much smaller apparatus to accomplish the same purpose.

It is claimed that a good absorbent gel will retain about 25 per cent of its own weight of coke oven benzol at 25° C., and that it will freely give up this amount when it is treated with slightly superheated steam, about 250° C. or lower. It is also claimed that the gel will absorb the benzol from a relatively dilute air-benzol or gas-benzol mixture, and that the final degree of saturation will depend upon the partial pressure of the benzol in the gas.

One style of plant proposed for carrying out the process consists of three absorption units, in form somewhat similar to the standard purifier box employed in gas works, and these three boxes are charged with gel, or other base exchange silicates, in pieces ranging in size from 8 to 14 mesh. The gas is freed from naphthalene, tar, and, if possible, sulphur, and it is then passed through two boxes in series. Box No. 1 removes benzol for a considerable period, but at the end of about eight hours the benzol begins to appear in box No. 2, where it is taken up by fresh gel. This causes a change over, and box No. 2 now becomes the first box to receive the rich gas, while box No. 3 acts as the safety box. In the meantime box No. 1 is being treated with steam for the recovery of the benzol, and as this is a much more rapid process than is absorption, it is possible to let the box cool for several hours after it has been steamed and before it is again shunted into the absorption cycle. The boxes are fitted with cooling tubes to prevent the heat of absorption from raising the temperature of the gel during the stripping operation, and if the box should for any reason be required at the earliest possible moment after the removal of its benzol burden a stream of water is circulated through these tubes to hasten cooling.

This system claims many advantages over the oil absorption process, such as very little attendance; large volumes of circulating oil are dispensed with; and the general operating and maintenance charges are claimed to be lower. The size of the plant is also considerably decreased, and, for an example, it is claimed that if absorber No. 1 has retained only 16 per cent (instead of 25 per cent) of its weight of benzols when it is shunted off for steaming, and if it is assumed that 100 tons of coal are carbonized per day with a yield of 2,520 pounds of benzols, or approximately three gallons to a ton of coal, each of the three absorbers must contain 5,040 pounds of silica gel. Assuming that silica gel weighs 44 pounds per cubic foot, and allowing nothing for packing, spacing, grids, steam and cooling pipes and free space at the top of the box, the three absorbers would have a total cubic capacity of 345 cubic feet. This would mean the passage of 6 cubic feet of gas per cubic foot of gel per minute in an 8-hour run.

The initial capital invested should also be much less than in an oil absorption plant, but there is no definite information on hand at present which will permit of making any comparison between the wet and dry systems with regard to efficiency and cost of operation. Definite figures are on hand as regards both the efficiency (which is very high) and the cost of operation (which is not excessive) of the oil absorption system, and it is to be hoped that something definite regarding these two important features will soon be learned as regards the dry system, or that some figures will either substantiate or disprove some of the large claims now being made by the advocates of this system.

The makers of silica gel have recently departed from this intermittent box process, and have devised a plant as

(*Continued on Page 192*)

War-Time Nitrogen for Peace-Time Agriculture

By

WILLIAM H. ROSS

NITROGEN is a common constituent of all explosives and in the form of nitric acid constitutes about 25 per cent of the total materials used in their manufacture. Nitric acid differs from most of the materials which form a constituent part of explosives in that it is prepared from inorganic rather than from organic sources. It has also the distinguishing feature that the greater part of the material from which it is prepared has been obtained in the past from sources outside the United States.

The World War sharply emphasized the danger of depending on foreign sources for a material of such military importance and accordingly active steps were taken during the early part of the war to prepare inorganic nitrogen compounds from the only known sources in this country, viz., by-product ammonia and the nitrogen of the air.

No prediction can be made as to what quantity of nitrogen will be required in a future war. It may be pointed out, however, that the greatest annual consumption which has so far taken place in the history of this country occurred during the war year of 1918, when the quantity used in explosives amounted to 135,800 tons as nitrate nitrogen and 15,200 tons as ammonia nitrogen, or a total of 151,000 tons.

Nitrogen in Fertilizers

Statistics on the annual consumption of nitrate, ammonia and organic nitrogen in the fertilizer industry are listed in Table I.

Table I. Consumption of Nitrogen in Commercial Fertilizers in the United States

Fertilizer material	Percent nitrogen in material	Nitrogen contained in material in net tons		
		1913	1917	1918
Nitrate of soda	15.6	40,600	44,300	36,400
Ammonium sulfate	20.6	26,800	25,100	20,700
Miscellaneous inorganic materials	---	2,800	8,900	1,900
Total inorganic nitrogen	---	70,200	78,300	59,000
Cottonseed meal	6	46,200	50,100	49,400
Tankage and blood	0.43	26,000	27,600	20,100
Miscellaneous organic materials	0.07	16,500	22,200	23,300
Total organic nitrogen	---	88,700	99,900	92,800
Total Nitrogen	---	158,900	178,200	151,800

The results given show that the normal peace-time consumption of nitrogen in fertilizers exceeds the greatest demand that has ever been made in this country for its use in explosives, but the inorganic nitrogen in the former only amounts to about 42 per cent of the total or to about 45 per cent of that used in explosives during the year 1918.

It is now generally recognized, however, that the present tendency in the fertilizer industry is not only towards a greater use of fertilizers in general but also towards a greater relative consumption of inorganic nitrogen as compared with organic nitrogen and under such conditions as will the more readily utilize in time of peace the ordnance war-time requirements for these compounds.

Factors Which Regulate the Composition of Fertilizers

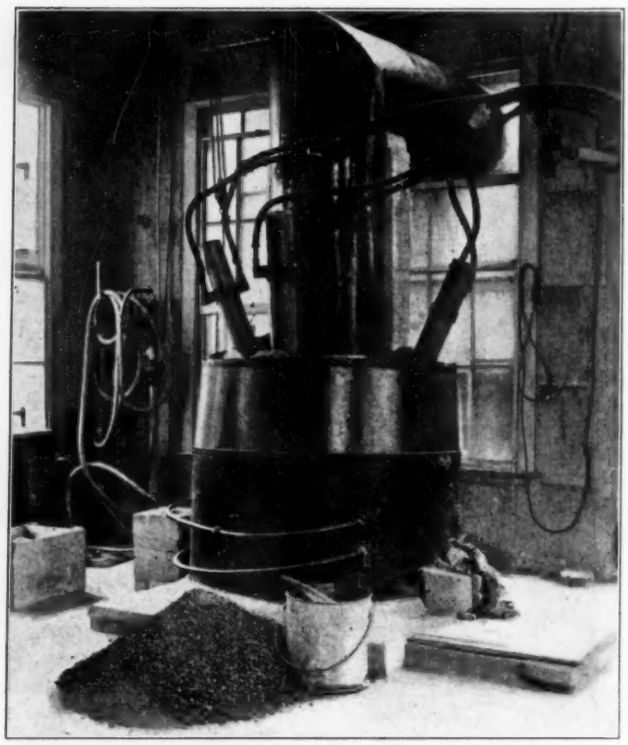
The most important factor which regulates the materials used in fertilizers is supply. All organic nitrogenous materials which have heretofore been used in fertilizers are obtained as by-products from other industries, principally the meat-packing and the cotton industries. Although these industries have grown steadily during the past 20 years their growth has not been nearly so rapid as the growth in the consumption of fertilizers. Furthermore, many of these by-product materials such as tankage, fish scrap and cottonseed meal, while ranking as comparatively low-grade fertilizer materials, serve as high-grade feeding stuffs by reason of their high protein content. The prices which they bring as feed for stock is therefore in excess of that quoted for inorganic fertilizer salts containing an equivalent amount of nitrogen. Their use in fertilizers is consequently diminishing and is attended with a corresponding increase in the use of inorganic nitrogen.

The ammonia recovered in the coking of coal, being an inorganic product, is not applicable for use in feeding stuffs and is therefore available for use in fertilizers, but the output of an industrial by-product such as this is dependent on the sale of the principal product and can therefore not be increased independently of the latter to meet an increased demand for the by-product. The amount of coke produced in by-product ovens increased from 25 per cent of the total in 1911 to 75 per cent in 1922. Unless new uses are found for by-product coke future expansion in the production of ammonia from this source is limited. The nitrogen of the air therefore remains as the only domestic source of this element to supply any marked increased demand for its use in fertilizers.

A second disadvantage attending the use of organic ammoniates is the cost of handling and transportation. The nitrogen content of the organic materials used in fertilizers at present is comparatively low, amounting to only about 9 per cent as a weighted average over a period of five years. The corresponding values for the phosphoric acid and potash-bearing materials consumed in fertilizers are 16 and 25 per cent, respectively. When these products are compounded into fertilizers the concentration of the resultant mixture must always be less than that of the highest grade material used in its manufacture. Complete fertilizers have been prepared containing as low as 10 per cent of total plant food constituents and for many years the average composition of the mixed fertilizers of the country could be represented by the formula, 2-8-2, *i. e.*, 2 per cent of ammonia, 8 per cent of phosphoric acid and 2 per cent of potash in the mixture. A fertilizer containing the same amounts of plant food constituents can be made by mixing as low as 17 parts of inorganic salts with 83 parts of inert material.

Advantages and Disadvantages of Low-Grade Fertilizers

If low-grade materials could be obtained in unlimited quantity near all points of consumption there would perhaps be little economy in increasing their concentration for it is recognized that the use of such materials may offer certain advantages which may be lacking in those of a highly concentrated nature. These advantages include: (1) They afford a market for low-grade by-products which would otherwise be wastes in the industries; (2) the fertilizing constituents which they contain may vary greatly in availability and thus serve as a source of food supply for the plant during the entire growing season; (3) while many of their constituents, such as sulphur and the different forms of organic matter add nothing to the commercial value of a fertilizer they nevertheless may have a beneficial effect on many soils; (4) many low-grade materials are of good physical condition and when used in fertilizers improve the physical condition of the whole mixture; and (5) small applications of plant food per acre can be made more conveniently in the form of low-grade than very high-grade materials.



Electric Furnace for Volitalization of Phosphoric Acid from Phosphate Rock, Arlington Farms Laboratory

It frequently happens, however, that the source of many low-grade fertilizer materials is far removed from districts of greatest fertilizer consumption and the cost of handling and transporting to such localities may be greatly in excess of the original cost of the material. This disadvantage has long been recognized and considerable advance has already been made in increasing the concentration of many materials which require shipment to distant points. Commercial Chilean caliche containing as low as 15 per cent of nitrate is refined before shipment to a product of 90 to 95 per cent purity. A portion of the German potash salts which are shipped to this country have been enriched from about 9 per cent to 60 per cent potash; while a large proportion of the western salts that have been produced since the war have been refined from a relatively low-grade material to one containing as high as 62 per cent potash. By the proper selection of these and other materials the average analysis of mixed fertilizers has undergone a gradual increase, amounting to about 30 per cent in the past 10 years.

It is generally admitted, however, that fertilizers of still higher concentration are desirable and an active campaign is now being made to further increase the analysis of mixed fertilizers and also to limit the number of brands manufactured. This was clearly emphasized by the action taken at each of five conferences held during the past few months at Chicago, Boston, Baltimore, Shreveport and Atlanta and attended by agronomists of various states and representatives of manufacturers selling fertilizers in these states. At these conferences a total of 52 fertilizer mixtures were recommended varying in composition from 14 to 32 per cent of plant food constituents with an average of 18 per cent. This represents an increase of about 51 per cent over the average mixed fertilizer of a few years ago.

The main phosphatic fertilizer material is acid phosphate which constitutes about 60 per cent of the total materials used in mixed fertilizers. The phosphoric acid in this material varies from 14 to 18 per cent with an average of about 16 per cent. The extent to which the concentration of fertilizers can be increased by present methods of manufacture is therefore limited by the percentage of phosphoric acid in acid phosphate.

Correlation of Phosphoric Acid Manufacture With Nitrogen Fixation

In recent experiments made at the Bureau of Soils and elsewhere it has been found that phosphoric acid can be volatilized from phosphate rock at a much lower temperature than has generally been supposed, and the possibilities are therefore promising where cheap power is available that the volatilization method may ultimately compete with the sulphuric acid method in the treatment of phosphate rock. The newer method has the advantage of yielding an acid directly of most suitable concentration for combining with ammonia and for making, by substitution for sulphuric acid, many other concentrated materials such as the phosphates of sodium and potassium.

The electric furnace method of preparing phosphoric acid in common with other electro-chemical processes should operate continuously when once started but as the labor requirements are relatively small compared with the normal cost of power, this process can be more conveniently applied to the use of secondary power than is true of most industries.

When dependence is placed on water power for the production of explosive materials it is very essential that the maximum power requirement will always be available at any season of the year. The completion of the power development at Muscle Shoals will make available in addition to such primary power a relatively large amount of secondary power for use during a certain portion of each year. Owing to its limited application, secondary power is always cheaper than primary and when it becomes available at Muscle Shoals the production of phosphoric acid offers special promise as an economic secondary industry in connection with the fixation of nitrogen. When nitrogen is fixed as ammonia it is obtained in its most concentrated combination. Ammonia as such, however, cannot be used directly in fertilizers and becomes suited for this purpose only when neutralized with an acid such as sulphuric or phosphoric. When neutralized with sulphuric acid the nitrogen content of

the resultant product is reduced to 20.6 per cent. Phosphoric acid differs from sulphuric acid in that it contains an essential fertilizer constituent, but it likewise is unsuited for direct use as a fertilizer until neutralized with a base such as ammonia. When both materials are combined to make mono-ammonium phosphate a product is obtained which contains two fertilizer elements instead of one with a total concentration of 76 per cent. It fortunately happens that the phosphoric acid prepared by the volatilization process can be recovered in most suitable concentration for yielding a dry product directly in neutralizing with ammonia. The fixation of nitrogen as ammonia for war-time use in explosives or peace-time consumption in fertilizers and the pyrolytic method of preparing phosphoric acid are therefore supplementary to one another not only in the use of power but in the fertilizer utilization of the materials which they produce.

Although ammonia is used to some extent in fertilizers the great bulk of American military explosives is prepared by treating an organic base with nitric acid. If dependence is to be placed on domestic sources for future supplies of nitrogen for explosives, methods for its preparation as ammonia must in turn provide for its oxidation to nitric acid. Available methods for making nitric acid offer the possibility of preparing for peace-time use in agriculture such other concentrated fertilizer salts as ammonium nitrate and potassium nitrate through reaction of nitric acid with potassium chloride. By replacing the acid radical in a potash salt a fourth concentrated material may be prepared containing both potash and phosphoric acid.

Ammonium nitrate is used directly in explosives, but its hygroscopic properties seriously interfere with its use for this purpose as well as for fertilizers. The three remaining compounds, viz., mono-ammonium phosphate, mono-potassium phosphate, and potassium nitrate, represent combinations of all three of the essential fertilizer elements in groups of two and all possess chemical and physical properties which make them admirably suited for use in fertilizers.

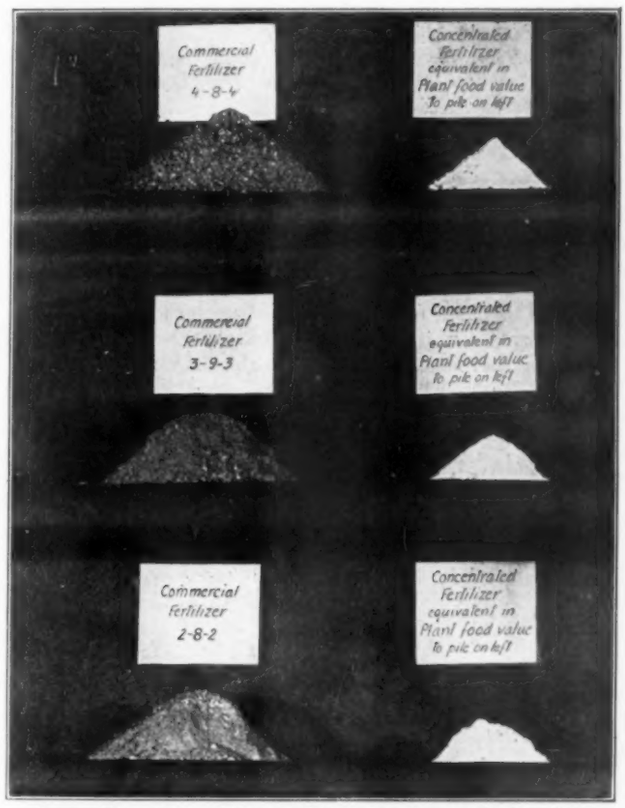
The possibility of combining these compounds in mixtures with fertilizer ratios corresponding to any given fertilizer formula may be readily determined by means of the system of triangular plotting as developed by the Bureau of Soils. In this way it has been shown that fertilizer ratios corresponding to 17 of the 52 fertilizer formulæ recommended for adoption at the five fertilizer conferences already referred to, can be prepared from mixtures of mono-ammonium and potassium phosphates with potassium nitrate; 24 others from one, two or all three of these salts in mixtures with an ammonium salt as ammonium nitrate; and the remaining 11 from one, two or all of the same salts in combination with a phosphoric acid or potash salt. These mixtures not only contain the fertilizing elements in the same relative proportions as in the standard fertilizer formulæ, but, being highly concentrated, they afford a means of reducing to a minimum the cost of handling and transporting the essential constituents of fertilizers.

The weights of these concentrated materials required to give the same quantity of plant food constituents as in a ton of several well-known standard fertilizers are given in Table II. The results show that for the fertilizer formulæ listed in the table the weights of the concentrated salts amount to from 15.7 to 26.7 per cent of the corresponding standard fertilizers which also represents the relative freight costs in the shipping of these materials.

Table II. Weights of Concentrated Salts Required to Give the Equivalent in Plant Food Constituents of 2,000 Pounds of a Standard Fertilizer

Fertilizer formula	Weights of concentrated salts $NH_4H_2PO_4$	KH_2PO_4	KNO_3	NH_4NO_3	Total	Total salts in percentage of corresponding standard fertilizer
	lbs.	lbs.	lbs.	lbs.	lbs.	
2 - 8 - 2	215.9	51.3	47.7	----	314.9	15.7
2 - 8 - 2	161.5	115.6	----	37.8	314.9	15.7
2 - 10 - 4	199.4	147.4	62.3	----	409.1	20.5
2 - 10 - 4	128.5	231.3	----	49.3	409.1	20.5
3 - 8 - 5	210.1	58.0	171.5	----	439.6	22.0
3 - 8 - 5	14.7	289.2	----	135.7	439.6	22.0
3 - 9 - 3	275.2	19.4	114.4	----	409.0	20.5
3 - 9 - 3	145.0	173.5	----	90.5	409.0	20.5
4 - 8 - 4	63.7	231.3	----	165.8	460.8	23.0
4 - 8 - 4	259.3	----	171.7	29.8	460.8	23.0
4 - 10 - 4	128.5	231.3	----	143.2	503.0	25.1
4 - 10 - 4	324.0	----	171.7	7.3	503.0	25.1
5 - 8 - 5	14.9	289.1	----	229.6	533.6	26.7
5 - 8 - 5	259.2	----	214.7	59.7	533.6	26.7

An objection to the use of concentrated materials may be raised on the grounds that commercially pure salts may be lacking in certain plant food constituents such as sulphur, magnesium, and manganese which are essential to


Commercial Fertilizer 4-8-4
Concentrated Fertilizer equivalent in Plant food value to pile on left
Commercial Fertilizer 3-9-3
Concentrated Fertilizer equivalent in Plant food value to pile on left
Commercial Fertilizer 2-8-2
Concentrated Fertilizer equivalent in Plant food value to pile on left

Comparative Bulk of Commercial and Concentrated Fertilizers

plant growth, and that the use of such materials may therefore be less satisfactory than lower-grade fertilizers which contain these additional elements. It must be recalled, however, that the soil is the great store-house of the ignorganic food of the plant. The materials which are consumed by most plants in largest amount are nitrogen, phosphorus and potassium and these elements have to be supplied to the soil in largest quantity. A sufficient application of a low-grade fertilizer to supply the required amount of nitrogen, phosphorus and potassium will necessitate a needlessly large application of other constituents. The use of concentrated fertilizers is therefore recommended, not with a view to replacing lower grade materials where these may be economically used, but as a means of transporting at least expense the bulk of plant food materials from different sources of production to the various points of consumption, there to be used in increasing the nitrogen, phosphorus and

potassium content of low-grade fertilizers, or for direct application to the soil when the use of other materials is found to be necessary.

It is in this direction that present developments in fertilizer manufacture are now tending and it is therefore concluded that the ordnance requirement for inorganic nitrogen compounds can best be utilized in peace time for agriculture by combining these compounds with phosphoric acid and potash in the preparation of concentrated fertilizers.

Past and Possible Future Growth in the Use of Nitrogen in Fertilizers

In the 10 years previous to 1914 the use of commercial fertilizers more than doubled, the rate of growth in each 5-year period being substantially the same. During the war the use of fertilizers decreased owing to their high cost, the low price of cotton and the embargo on German potash. Since the war their consumption has been irregular owing to unfavorable agricultural conditions. The increase in the use of fertilizers during the past 20 years from 2,200,000 tons in 1900 to 7,639,000 tons in 1920, or upwards of 200 per cent, is therefore less than would reasonably be expected under normal conditions. The increase during the same period in the production of the materials which constitute the principal domestic sources of nitrogen, viz., cottonseed, coke and slaughtered animal wastes, amounted to 9, 150 and 11 per cent, respectively. The weighted average increase in the maximum possible production of by-product nitrogenous materials from these sources for the same period is only about 40 per cent or less than one-fifth of the corresponding increase in the use of fertilizers. If it be assumed that all these materials increase in the same proportion during the next 20 years and that one-third of the total nitrogen they contain be used in fertilizers as at present, it will follow that about two-thirds of the nitrogen required in fertilizers, equivalent to about 400,000 tons, must be obtained by nitrogen fixation or from sources outside the United States. This amount of inorganic nitrogen greatly exceeds the maximum so far required in this country for use in explosives.

It may be emphasized further that the use of commercial fertilizers is only one of several means which may be applied to bring about increased growth of crops. If means can be found, as some think possible, for materially reducing the cost of nitrogen compounds, their consumption in fertilizers would undoubtedly increase at a very much greater rate than would be true of other commodities whose use is essential irrespective of cost.

In Table III it is shown that the total fertilizers used in 1920 only amounted to 41 pounds per acre under crops, and the estimate which is also given of the total requirement of nitrogen, if all land under crops throughout the country received the same general average as for land under crops in the New England States, emphasizes the possibilities of future expansion in the use of fertilizers in this country. The data given in the table further shows that the greatest rate of increase in the use of fertilizers is now taking place in the North Central and Western States which are far removed from the sources of most fertilizer materials, and it is in such states that the use of concentrated fertilizers should effect greatest economy in the cost of transportation.

Table III.—Sectional Increase in Use of Fertilizers, 1910-1920, and Additional Nitrogen Required to Equal Per Acre in Crops Consumption in the New England States

States	Increase in use of fertilizers 1910-1920 per cent	Fertilizers used in 1920		Total nitrogen in fertilizers in 1920, estimated 27 per cent—tons	Additional required to equal per acre in crops consumption in New England States—t ns
		Total tons	Per acre in crops—lbs.		
New England		341,450	146	9,200	
Middle Atlantic	10	876,685	97	23,700	12,000
North Central	76	847,282	9	22 900	348,600
South Atlantic	32	4,510,705	255	121,800	
South Central	16	967,982	24	26,160	132,700
Mountain	64	7,000	0.7	200	41,500
Pacific	51	68,136	8	1,800	31,000
Total for U. S.	29	7,619,240	41	205,700	565,800

Industrial Preparedness in Chicago

An enthusiastic meeting of the Army Ordnance Association of Chicago, attended by Honorable Dwight F. Davis, Assistant Secretary of War, was held in that city on October 5th. Colonel Davis, upon his arrival, was met by Mr. Russell, Chief of the Chicago Ordnance District. During the forenoon several calls were made on business men in Chicago, and at noon an informal luncheon at the Chicago Club was given, to which Mr. Russell had invited 20 of the prominent men of the district. Those at the luncheon included Honorable Dwight F. Davis and Messrs. E. A. Russell, F. H. Jones, Alex. Legge, J. J. Mitchell, B. L. Winchell, George A. McKinlock, Alfred Granger, James O. Heyworth, Hale Holden, Thomas W. Hinde, Marvin Pool, Arthur A. Bevan, Robert P. Lamont, Wm. P. Martin, and Everts Wrenn.

During the afternoon Colonel Davis was taken to Fort Sheridan to view the work being conducted there by General Moseley; and in the evening a dinner was given at the University Club for seventy people, among whom were included the Chicago District Ordnance Advisory Board, representative manufacturers of this district, members of the Chicago District Ordnance Association, those officers engaged in the industrial war plans of all supply branches; the principal officers from the Sixth Corps Headquarters, and General Moseley of Fort Sheridan.

Mr. Russell first introduced the Assistant Secretary of War, who addressed the assembly on the question of Industrial Mobilization as it affects all branches of the service, and expressed his deep gratitude to those present for the very earnest efforts they were putting forth in solving the problems of industrial mobilization in all its phases. General Dawes was then introduced and emphasized the need for careful study of industrial preparation, picturing in his characteristic and vivid manner, by experiences of his own, the impotency of man without machines. He closed his remarks with a forceful declaration of the platform of the Minute Men.

General Moseley concluded the program by a very entertaining discussion of the Department's method of bringing to a higher standard the man-power of the nation. He discussed the desire of the Department to organize the school system of our country to include such training as is now given at the Citizen's Military Training Camps, the idea being to foster a desire in the youth for good government and preclude the possibility of "red ideas" maturing in their minds before a clear understanding of our present wholesome institutions.

Notes on Localized Enlargements of Machine-Gun Barrels*

By

W. W. DE SVESHNIKOFF

ENLARGEMENTS sometimes occur in the bores of machine-gun barrels at a short distance from the origin of rifling and at various points near the muzzle. It is known, in firing a large number of rounds, that the greatest destruction of the bore takes place at the short distance from the origin of rifling (see Fig. 1). As stated in Tech. Paper 191†, this effect has been attributed to the stream of hot gases which upon leaving the cartridge may be partially deflected by the shoulder and the neck of the shell, being directed toward a zone at some distance from the origin of rifling where maximum temperature is reached. This effect is not found in large guns where the cartridge case has a cylindrical form.

In Fig. 1 it can be seen that with water-cooled guns, such as Browning type, this zone near the breech marks the region of greatest destruction. Water-jacketing prevents the development of a swelling in this zone. On the other hand, the gradual increase in temperature in air-cooled barrels, produced by prolonged firing will reach a considerable intensity at this particular zone, causing a swelling as is shown in Fig. 2.

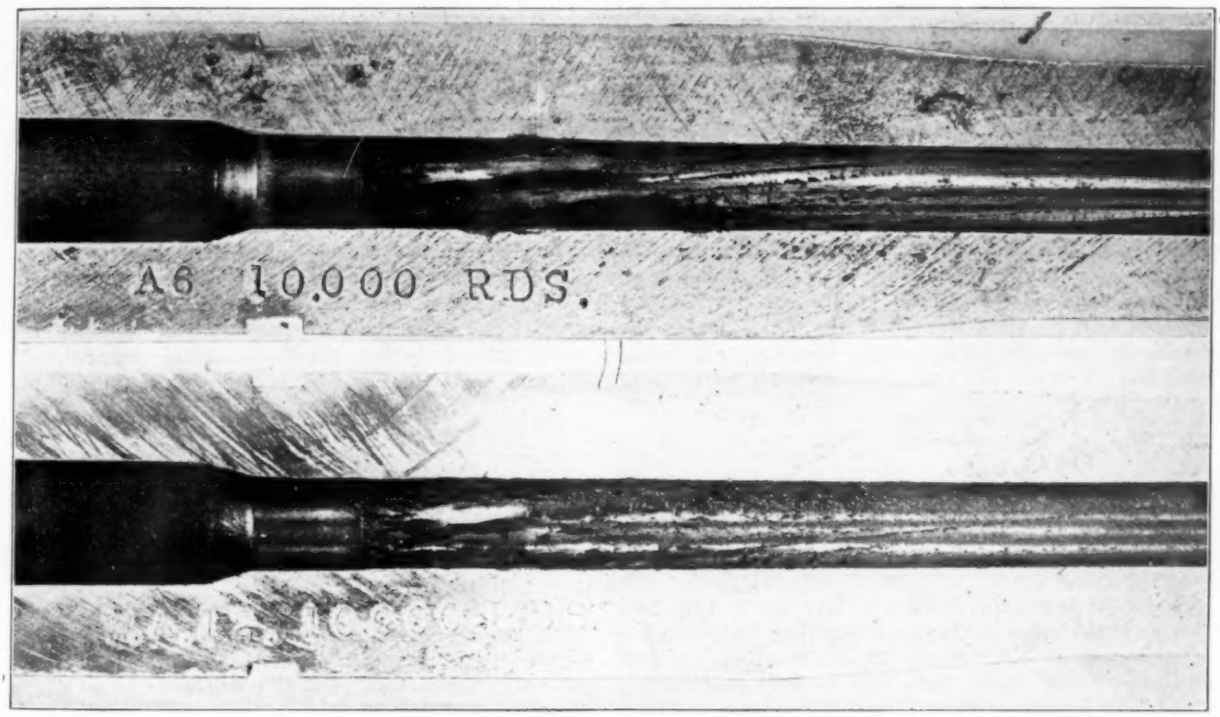


Fig. 1. Point of greatest destruction at the breech as it appears in water-cooled guns

The slight swelling of the barrel near the breech end to the degree shown in Fig. 1, should not severely affect the accuracy of the rifle. Swelling in extreme cases, as in the case of air-cooled guns, will develop into failure by the rupture of the barrel. On the other hand, the swelling of a barrel at the various points near the muzzle has an ap-

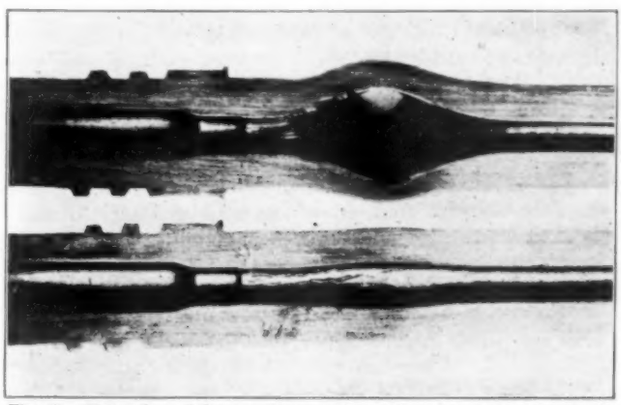


Fig. 2. Examples of bore enlargements at the breech of air-cooled barrels. Upper: Extreme case, continued firing up to 20,000 rounds. Lower: Fired about 10,000 rounds.

*From reports on erosion research, undertaken jointly by the Bureau of Standards and the Small Arms Division of the Ordnance Department.

†Bureau of Standards, Technologic Paper 191.

preciable effect on the accuracy of the gun. The muzzle enlargement in a water-cooled barrel is usually located at the end of the water jacket. The barrel experiences a sudden change in the rate of surface cooling in this region.

The location and the magnitude of the enlargement probably depends upon the difference in the cooling rate caused by air cooling at the extreme end of the muzzle and water cooling over the rest of the barrel. This difference in cooling can be observed by comparing the temper color produced on the outer surface of the bore at the portions which extend from the water jacket barrel.

It is known that the muzzle velocity of the bullet is an important factor in the accuracy of the gun. A bore enlargement will permit a leakage of the gases, thereby decreasing the pressure. The velocity therefore will be reduced and the bullet will lose effectiveness as far as accuracy is concerned. From the muzzle end of the barrel, the distance of a bore enlargement near the muzzle, appears to be closely related to the accuracy of the rifle; the enlargement nearest the muzzle produces an earlier loss of accuracy. Muzzle swelling is illustrated on barrels in Fig. 3.

Of course it should be remembered that the total number of rounds fired, the number fired at each burst, the rate of firing, the time intervals between bursts, and the type of ammunition used affect the temperature of the barrel and the degree of swelling.

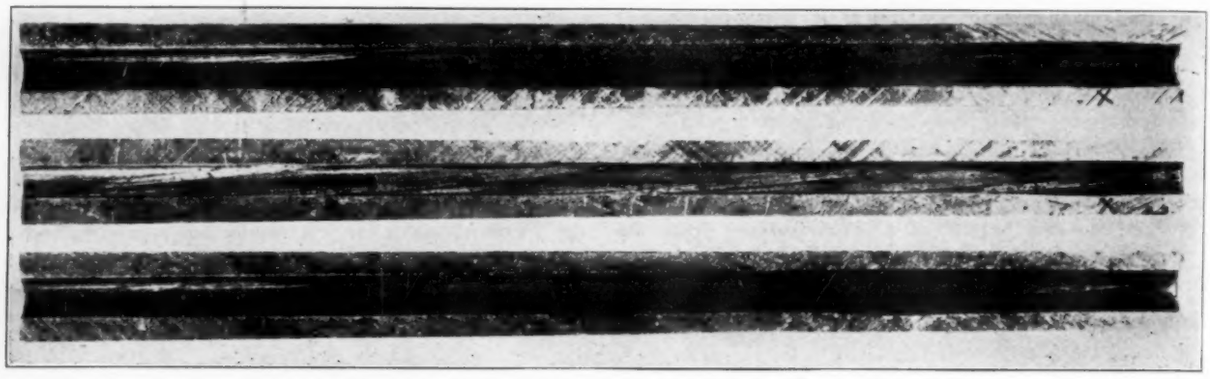


Fig. 3. Muzzle swelling of water-cooled guns. X marks location of enlargement

There is no doubt that water-cooled barrels are more efficient in service than air-cooled barrels from the standpoint of erosion, especially if the firing is carried out at a rapid rate. However, the muzzle swelling of some of the water-jacketed barrels forms an obstacle that must be overcome in the development of the present types of guns.

Uncle Sam Is Awake

"Naive surprise expressed a few days ago by President Coolidge at the alacrity with which European statesmen had picked up his off-hand remark of several weeks ago that the United States stands ready now as previously to step in and help Europe whenever she is asked, had a parallel in the expressions of genuine astonishment voiced by members of the American Iron and Steel Institute last Friday as they marvelled at the armament wonders being shown them at the Government proving grounds at Aberdeen, Md.

"President Coolidge had full knowledge, of course, of all the elements underlying the European political and economic situations. And likewise the members of the Institute knew all about the various grades and forms of iron and steel which enter into the building of the monster ordnance, machine guns, field artillery, aeroplanes, projectiles of all sorts and sizes at Aberdeen. But in both cases the surprise grew out of the combinations into which these elements—on one hand political and on the other the ferrous and nonferrous—had been worked by deft hands directed by keen brains.

"No member of the Institute who spent last Friday at Aberdeen needs further proof that the "next war" will be even more hellish than was the last great struggle, compared with the wars which General Sherman had in mind when he uttered his immortal aphorism. Every man went away more determined than ever, if possible, to be an advocate of peace—and preach it with his mind's eye fixed upon Aberdeen.

"Every member also went away with far higher respect for the United States Ordnance Department and for its gallant chief, Major Gen. C. C. Williams, whose guests the members of the Institute were upon this memorable occasion; and respect for not only General Williams but also for all the splendid men of the Department.

"And, too, every observer left the grounds firm in the viction that Uncle Sam has been anything but "asleep at the switch" in the development of any and every branch of the service since "Armistice Day" became history on Nov. 11, 1918. If this demonstration had been staged deliberately to impress the outside world of America's wideawake preparedness it could not have been managed better. The Ordnance Department today has many hundreds more of rather bewildered, astounded but enthusiastic friends and supporters than before that Aberdeen trip."—(Editorial in *Daily Metal Trade*, Cleveland, Ohio, October 30, 1923.)

The German Long-Range Gun

PART II

By

H. W. MILLER

The projectile as used with the guns while firing on Paris is shown in Figure 1. The original diameter of this projectile was 210 millimeters but the projectiles which arrived in Paris from the position of the village of Ham, north of Noyen, were 240 millimeters in diameter. This drawing has been made from examination of the fragments of a large number of projectiles carefully collected in Paris as they fell. To the best of our knowledge there were no duds, hence all information has been gained from study of fragments, and the best possible reconstruction from fragments.

"Herr von Eberhard, Rausenberger's assistant, figured out a new form for the point of the shell, a form which subsequent tests proved to be correct. . . . The first trials were made at the marine proving ground at Altenwalde near Hamburg, with a diminished load of powder. They were satisfactory and we then proceeded to a full charge. The results brought general consternation. All calculations appeared vain. The projectiles fell wherever it suited them but in no case where we had reckoned that they should fall. One shell which should have gone forty-five miles actually flew fifty. Another calculated for the same distance landed but thirty miles away. . . . Then came the first ray of light. Well to one side of the line of fire a big iron object had crashed through the roof of a peasant's house and gone through into the cellar. Investigation disclosed that the object was the point of the projectile, which had been loosened from the body of the projectile by the tremendous friction in the gun.

"On the heels of this came the finding of a projectile which had buried itself deep in the earth. The copper guide-ring which engages the rifling and gives the shell its twist had been stripped off clear and clean in the passage through the long barrel. We improved the method of fastening the nose to the shell and, after brass guide rings had also failed to withstand the friction, iron was used. With the new point and the iron guide ring, the gun was fired once more. . . . The shell fell exactly were our calculations had shown that it should fall. The problem was solved." (7.)

The projectile as finally designed is unusual in several respects. The stresses set up in the original copper rotating bands being such as to sheer them, the shell was enlarged at two places in its length to permit grooves to be cut in the steel shell itself. There were 64 of these grooves and back of each grooved band a narrow copper obturating or gas check band was inserted. The shell was filled from the front and closed by a plug to which the false cap was attached. The cap had a radius of ten calibers, according to Langner of Skoda. The interior of the shell was divided into two parts by a steel diaphragm about 155 millimeters in diameter for the 210 millimeter shells and about 170 millimeters for the 240 millimeter projectiles. The diaphragm was perforated with seven holes and was screwed in place. Two fuses (percussion) were supplied, the one in the diaphragm and the other in the base, being inserted from the rear. The most logical reason for the diaphragm is that it was inserted to divide the charge and lesson the tendency of each part to pack from the effect of inertia on firing to the extent that it would fail to detonate. If this was the reason it was successful, for no shells failed to detonate. The 220-millimeter shells weighed 120 kilograms (264 pounds).

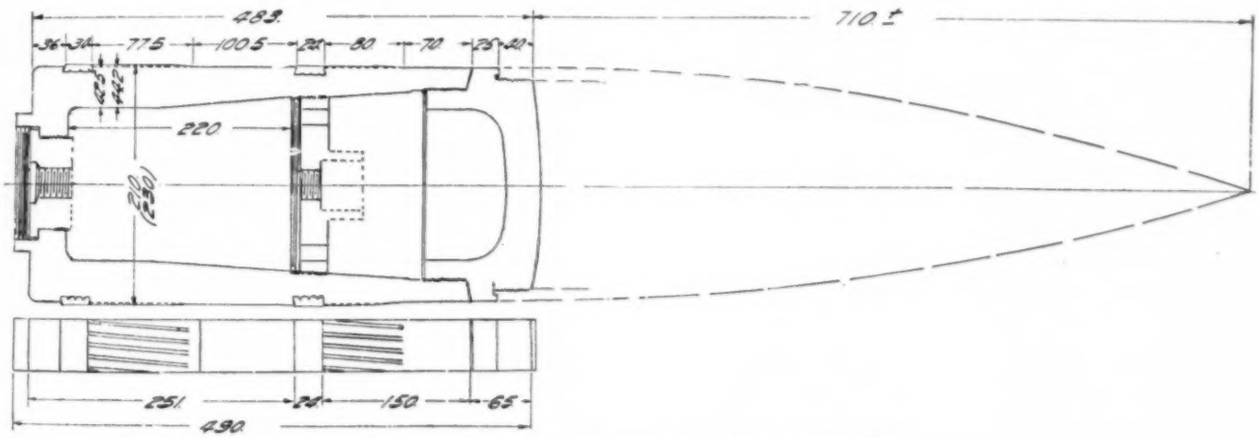


Fig. 1. Approximate Shape and Dimensions of Projectile

Two sets of tests, made at French laboratories, are available giving the chemical and physical characteristics of the metal of the shell.

Analysis of Various Parts of the Shell

	Shell	Cap Holder	Cap	Dia-phragm	Copper Band	Dunkirk Shells
C	0.6 to 0.8	0.6 — 0.8	0.10 — 0.18	0.60	----	0.72
Mn	0.3 to 0.5	0.3 — 0.5	0.41 — 0.97	0.09	----	0.26
Si	0.25 to 0.30	0.25 — 0.28	0.03 — 0.05	0.61	----	0.23
S	0.03 to 0.05	0.03 — 0.05	0.05 — 0.11	0.04	----	0.03
P	0.03 to 0.05	0.03 — 0.05	0.04 — 0.06	0.04	----	0.04
Ni	2.0 to 2.3	2.00 — 2.3	0.00 — 0.11	0.0	----	2.41
Cr	1.3 to 1.5	1.3 — 1.5	0.00 — 0.2	0.0	----	1.32
Pb	----	----	----	---	0.12	---
Fe	----	----	----	---	0.21	---
Cu	----	----	----	---	99.67	---

Elastic limit: 113,000 lbs., ultimate strength: 148,000 lbs., Brinnell hardness: 300—350

Micro-analysis: Steel, air hardened. Well formed crystals recognized notably near the exterior surface. No crystals noted near the interior surface. Apparently a steel casting forged only to the extent of piercing to form the cavity.

The second report noted above calls attention to the fact that in the bombardment which began on May 27 after a silence of twenty-five days, that is, since May 1, the projectiles arrived from a new battery location and the design of the projectile was different. First, the diameter had been changed to 240 millimeters. The base of the shell as shown on Figure 2 had been changed to a truncated cone, the angle of the base of the cone being 30 degrees. The number of grooves remained the same, that is, 64, probably to permit of the use of the same rifling mechanism in rifling the rebored 210 millimeter tube. The design of the rifling of the projectile had been modified slightly to increase its strength. The weight of this modified projectile has not been learned.

It was observed that successive series of projectiles which arrived in Paris were punch-marked to indicate that they had been sorted according to some characteristic. All projectiles marked with four punch marks would arrive and be followed by those stamped with five marks, etc. When the Germans had been driven back from the Marne salient in July, 1918, Colonel Blake had the opportunity to examine the position near Fere-en-Tardenois shortly after it had been captured and found there a series of wood crates in which the projectiles had been sent up. He reported finding the crates of series 10 nearly complete. Parts of numbers 7 and 13 were identified. These crates were provided with curved collars to fit the false cap of the projectile, thus insuring proper protection of the projectiles in transit. One explanation of the subdivision of the projectiles into series is that they were provided with slightly different characteristics to allow for and accommodate the condition of the lands of the gun as they wore. This wear was very rapid as a result of the friction between the steel lands of the projectile and the steel lands of the gun. Another explanation might be that the projectiles had been dynamically balanced and sorted according to their tendency to drift, deviate or yaw from the theoretical path or trajectory and that each series required a special correction for elevation or azimuth, or both.

It may be well to call attention to the fact that since the projectile was rifled it became necessary to attach the rammer to the base of it in such manner as to permit careful insertion of the lands of the projectile into the grooves of the gun. As soon as this was assured the projectile was rammed to the extent of causing the lands of the gun to bite into the copper obturating band back of the first rifled band of the projectile. The projectile would then remain in place when the gun was elevated to its firing angle of 55 degrees. Also, since the first lands of the projectile meshed with the grooves of the gun this would insure that the lands of the rear grooved band would also mesh as the projectile began to move.

The projectile contained about 18 pounds of high explosive. Attention is called to the shape of the cavity, allowing a great wall thickness to withstand the stresses set up by the maximum pressure of about 3,350,000 pounds exerted on its base. The small amount of explosive contained must have been a great disappointment to them, but there was no choice, for a weakening of the walls of the projectile would have caused it to upset in the bore of the gun and a premature explosion would have been the certain result.

The Powder Charge

We probably have less intimate and exact knowledge of the powder charge than of any other part of the gun and carriage. Commander Kinzel has given the powder pressure as approximately 67,000 pounds per square inch. The maximum normal service pressure for our own guns is 38,000 pounds. The research work incident to the development of the powder used by the Germans must have been considerable, and it is through this research work that they probably have profited most in the design and construction of this otherwise relatively valueless gun. The propellant commonly used in the German army is a nitro-glycerin powder usually in tubular form. It is believed that they used a special powder for this gun; probably special not only as to form, but as to composition as well.

Two of our Allies have seen fit to construct similar guns during the past few years. They too have found the economic caliber for such ranges to be approximately 8 inches, and the one gun has been given a caliber of 8.3 inches and the other 8.66 inches. For the first of these two guns the powder charge weighs 400 pounds, and for the second 441 pounds, the range in each case being 76 miles, or 121.5 kilometers.

"The powder case took up some 3 meters, or nearly 10 feet, in the gun, thrice the length of the projectile planned and about twice its weight." (7)

"The shells looked very tiny in comparison to the quantity of explosive which was to propel them. Even with heavy guns we were accustomed to seeing the cartridge about as long and thick as the shells. In this case the charge was three to four times the length of the shell." (9)

Twice the weight of the projectile would give a weight of 528 pounds for the weight of the powder charge. This is approximate only. The powder of the 400-pound charge mentioned above as developed by one of our Allies has been used in sticks about 15 inches long with elliptical cross-section of the dimensions of ¾ by 1 inch. This, too, is a nitro-glycerin powder. The powder used by the other of our Allies is in strip form and of a double composition; that is, each strip is made up of three layers, the outer of which are of the same composition and burn at a different rate than the center. Professor Langler of the Skoda works stated to the members of General Wheeler's party that they found it difficult to control the muzzle velocity, which would, of course, mean, to a certain extent, the rate of burning of the powder within a limit of less than 100 meters per second, that is, between 1,500 and 1,600 meters. This seems rather extreme and it is given only for consideration.

The powder charge was contained in a metal, presumably brass, case approximately 10 feet long and slightly more than 8 inches in outside diameter. It was transported to the field in its own crate, and the field service had nothing to do with it except to insert it in the gun. It is not improbable that no member of the field operating unit, except probably the admiral in charge and Commander Kinzel, knew what was in the case. The theory

has been advanced that this case was completely sealed with a metal disc soldered in at the forward end, the air exhausted from the interior and the case then charged probably under some pressure with an explosive mixture of hydrogen and oxygen. The usual type of primer was screwed into the center of the base and sealed against the escape of the gas. The firing of the primer then ignited the explosive charge of gas in addition to a possible priming charge in the base.

The Life of the Gun

The life of these guns has been placed variously at from 50 to 60 rounds at each caliber. The original 210-millimeter tube was sufficiently thick to permit reboring to 240 millimeters and later to 260 millimeters. The following table lists the number of projectiles which fell within and outside of the walls of Paris from day to day:

TABLE: BOMBARDMENT OF PARIS BY THE GERMAN LONG-RANGE GUN

(March 23 to August 9, 1918)

Dates		Number of projectiles Within the walls	Outside the walls	Killed	Wounded
March	23	18	3	15	36
	24	13	9	11	34
	25	4	2	1	3
	29	11	3	881	68
	30	18	3	10	60
	31	3	--	1	1
April	1	3	1	8	8
	2	3	1	--	3
	3	1	--	--	--
	6	2	4	--	3
	7	--	1	--	--
	11	5	1	9	21
	12	5	2	2	14
	13[2]	6	2	--	--
	14	3	1	--	--
	15[2]	3	2	--	--
	16	2	1	17	114
	19	1	2	--	--
	21	2	--	--	--
	24	--	1	--	--
	25	6	4	1	--
	26[3]	1	--	--	--
	30	--	3	--	--
May	1	--	1	--	5
	27[3]	7	7	4	20
	28	6	4	1	2
	29	5	5	1	7
	30	4	5	13	5
	31	1	3	--	--
June	1	--	4	--	--
	3	--	6	2	8
	4	4	--	4	16
	7	3	1	1	4
	8	1	2	3	--
	9	1	3	1	9
	10	2	2	3	13
	11	--	1	--	--
July	15	9	1	6	9
	16	4	--	3	8
August	5	13	4	32	61
	6	12	7	8	39
	7	8	4	7	43
	8	1	4	1	--
	9	2	10	3	6
Totals		183	120	256	620

[1] Shell struck an arch in the roof of the Church of Saint Gervais. [2] Night and day. [3] Night.

Major K. F. Adamson of the Ordnance Department has presented an analysis in the article listed under his name at the beginning of this discussion, calling attention to the rapid decrease in the accuracy of fire of successive guns. On the first day, that is, March 23, 86 per cent of the projectiles fired fell within the city walls. On the 29th only 25 per cent fell within. On the very next day 86 per cent again fell within, indicating almost certainly that a new gun was being used. The previous gun had then fired 53 projectiles. There were two causes for this rapid wear. The first was evident from examination of fragments of the projectiles which fell in Paris. The grooves in the copper obturating bands of the shell would have a width equal to the width of the lands of the gun. Each successive projectile that fell showed a decreased width of groove in the copper band until it appeared, when about 50 projectiles had been fired, that the gun lands had not sufficient strength left to prevent their being ripped out.

"One difficulty could not be overcome and never was overcome. The great charge of powder developed such terrific heat that every time the gun was fired the chamber at the breech became considerably larger and longer—the hard steel was simply melted away. After about sixty shots had been fired the gun had to be sent back to the factory, and its extreme life was about two hundred shots." (7)

This fits nicely with information reported by Major Barnes from the interview with the Krupp engineer to the effect that the metal powder case had been completely consumed; with the probable exception of the heavy base. We see here an interesting case of the temperature of the gases and the time of exposure of the breech section of this temperature passing the critical point. The period of travel of the projectile in the bore of the gun was probably greater than for such a gun as the 38-centimeter gun and the temperature of the gases at their pressure of 67,000 pounds per square inch was certainly very much greater. Normally the walls of the powder chamber are but little eroded because the period of exposure to the hot gases is not long enough to permit the walls to melt under the temperature attained by the gases. In this gun, however, with a tremendously higher temperature the powder case and the steel walls of the powder chamber would begin to fuse in a time perhaps equal to or less than the normal period of travel. It is to be noted that the powder case was a hermetically sealed container for the powder only and had no part in the obturation.

The Carriage

We probably need not attach much interest to the carriage from which these guns were operated. It is a matter of relatively minor consideration. Any type of carriage of sufficient strength and with provisions for permitting the proper elevation and a fine degree of adjustment in traverse would suffice. There seems to be sufficient foundation for the belief that all of the guns were operated from a single railway carriage of the type developed some time previous for the 38-centimeter guns from which these long-range guns were made. The writer had the opportunity to examine a 38-centimeter railway carriage identical with that shown in Part I of this article (page 99, ARMY ORDNANCE No. 20, September-October, 1923), in Brussels, and for a time was puzzled to find provisions in its design for a degree of elevation, for pressures in the recuperator cylinder, and for the operation of the elevating mechanism that were not necessary for the gun then mounted on it. Provision was made for an elevation of 55 degrees, which of course would not be used for the 38-centimeter gun. This carriage fitted perfectly to the steel platform or base found in the Bois du Chatelet, five miles north of Chateau Thierry.

"An epi of identical construction to the Bois du Chatelet epi was found near Fere-en-Tardenois immediately after the Germans had retired, but all the matériel had been withdrawn, leaving only a circular pit of the same dimensions as that occupied by the captured platform . . . allowing a perfectly logical deduction that the gun firing on Paris from the Fere position was of such a nature and dimensions that it could be fired from a platform identical with the captured one mentioned above." (3)

"The gun carriage and bed used near Fere-en-Tardenois had been further improved by unremitting work in the meantime. The bed no longer consisted of a concrete base (as found near Laon) but an iron platform which was constructed in such a manner that it could be moved,

bolted together, adjusted and prepared for the *railway gun* within a few days. An experienced detachment trained to handle heavy loads was of course necessary for this work." (9)

This carriage, although the model examined was labeled 1918, had apparently been designed, perhaps in a somewhat cruder form, quite a long time before. In discussing the 28-centimeter guns installed opposite Verdun shortly after the beginning of the war Commander Kinzel says:

"A plan was soon formulated to give the heavy guns a greater mobility than had hitherto been thought possible, and it was not long before the Navy in cooperation with Krupp had completed the first naval gun of the heaviest kind mounted on a railway carriage of 18 axles especially constructed for the purpose, . . . a railway carriage which had a total weight of . . . 270,000 kilograms and a length of 34 meters." (9)

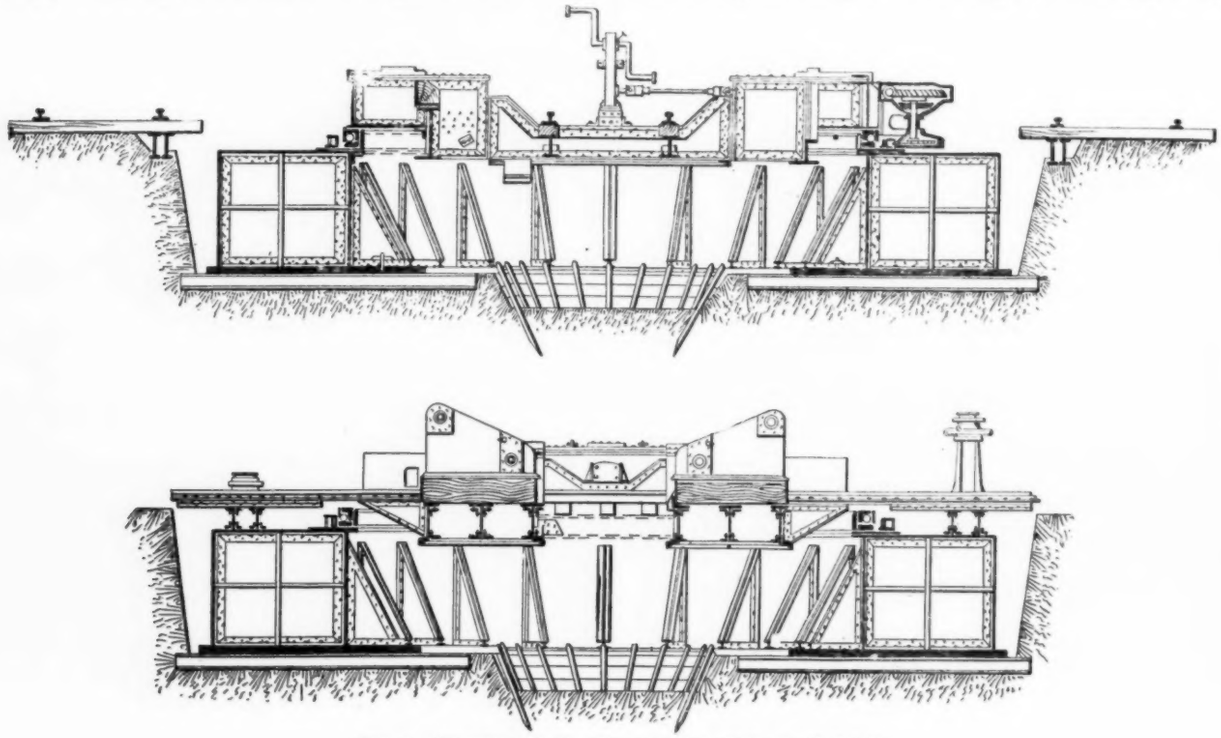


Fig. 2. Elevation of Gun Emplacement (Bois du Chatelet)

All of the above seems to indicate that the 38-centimeter carriage which was captured by the Belgian army and which is now in their possession was either the actual carriage or was identical with the carriage on which the long range guns were mounted. This carriage comprised a body of structural steel made up of two side girders connected by numerous heavy transoms. This body was supported on two-span bolsters which in turn were supported on two five-axle trucks in front and two four-axle trucks at the rear. The bottom chords of the side girder of the body are horizontal and are provided at the two ends with special cast steel pads which fit to complimentary pads on the steel firing platform. The gun is mounted in a cast-steel cradle carrying on its under side two hydraulic recoil cylinders permitting a length of recoil of about 1.3 meters. A single recuperator cylinder is mounted in the center at the bottom between the recoil cylinders. The extension of this recuperator cylinder to the rear is planed flat on both sides to serve as a spline or guide for the forked recoil lug of the gun which thus prevents rotation of the gun on firing. The top of the cradle is provided with two counterweights which may be dropped in traveling and raised when the gun is being operated to balance the tipping parts.

The elevating mechanism comprises two straight racks sliding in guides in the forward inclined bottom portion of the carriage, meshing forward with two heavy pinions on a cross-shaft operated through a gear shift either by a high or low-speed operating mechanism driven by two two-man cranks on either side. The rear ends of the racks are connected by links with the bottom of the cradle about on the center line of the recuperator cylinder and about midway of the cylinder. The high-speed mechanism was used to depress the gun for loading and elevating to approximately its firing position, and the low-speed mechanism for final fine setting in elevation.

The first platform from which these guns were operated was of concrete. This concrete foundation had a steel ring bolted to it which serves as the path for the conical rollers on which the rotating turntable or racer rested. There seems no reason to believe that the railway carriage described above was not used here as well as at the Fere position and that a steel racer somewhat of the design shown in Figure 2 was mounted above a steel roller path. The base used at Fere-en-Tardenois was of the design shown in this illustration. This platform was of structural steel and comprised a base of box-section resting on timbers and concrete, with a rotating section above resting on 112 8-inch steel balls. The base section is approximately 35 feet in diameter and 6 feet in depth. The racer is 28 feet in diameter. The racer carries two railway rails at right angles to the line of the pads which support the railway carriage. The spur track laid in from the main railway line led directly to the center of this platform, and when in mounting position the rails of the racer fitted with the rails of the spur track. A short section of the spur continued on the other side of the platform. The railway carriage was thus run into place over the firing platform, raised by four hydraulic jacks, the four trucks

run out forward and back, the racer rotated 90 degrees, and the carriage then lowered so that the cast-steel pads on the bottom of its side girders fitted with similar pads on the racer. The carriage was then bolted rigidly to the racer and rotated with it.

A spur gear rack was attached to the base section of the platform just outside of the ball path and the traversing mechanism, comprising a pinion meshing with this rack and driven through a vertical shaft by a worm wheel and worm, shafts, bevel gears, universal joints and hand-cranks mounted in a stand between the railway rails on the left side of the carriage. This platform permitted the gun to be rotated through 360 degrees if desired. It was installed by means of a Gantry crane mounted on two short auxiliary tracks on either side of the emplacement

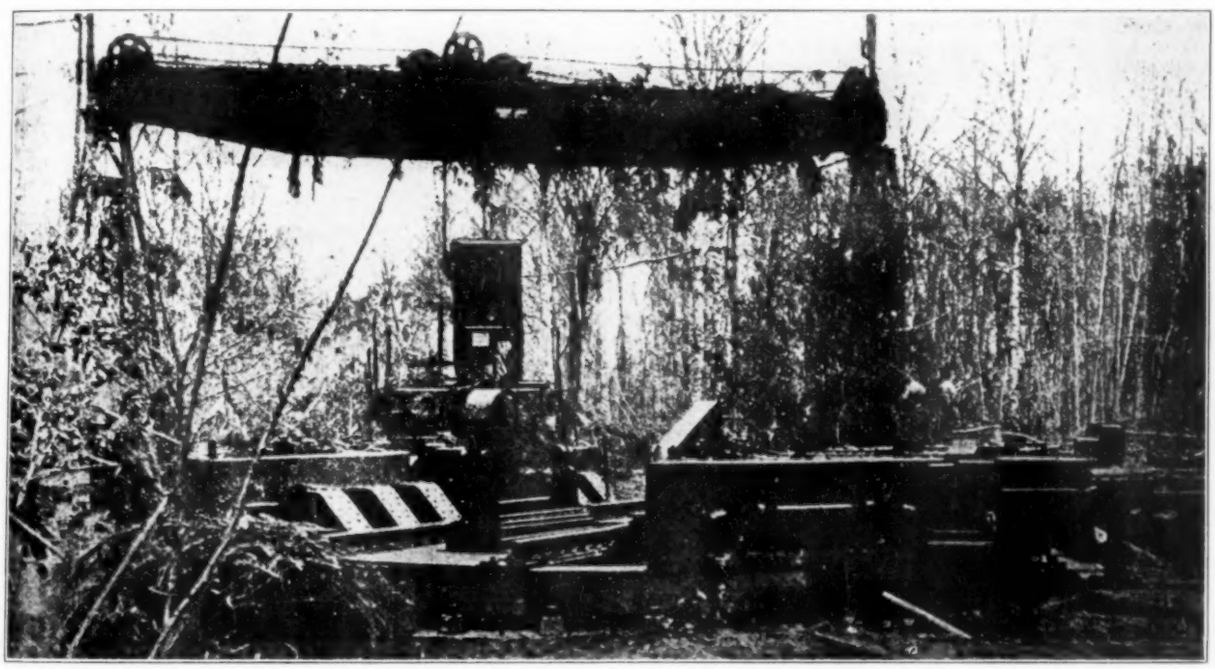


Fig. 3. Gun Emplacement and Gantry Crane Used in Installation

position, as shown in Figure 3. This same arrangement of tracks has been observed in all of the battery positions, even in the case of the concrete base near Laon. The Gantry crane was used there evidently to install only the steel racer.

Battery Positions

The long-range guns were operated to the best of our knowledge from only three positions. The first of these was approximately 122 kilometers from Paris and located near the city of Laon in a thick wood near the crest of Mont de Joie (Figure 4). The second was at the little village of Ham, on the main Laon-Amiens railway line and about 100 kilometers from Paris. The third was at Fere-en-Tardenois, already referred to, and about 10 miles north and slightly east of Chateau Thierry, about 80 kilometers from Paris. The first position mentioned above comprised three emplacements. A concrete base was found at the position marked α. The positions β and γ were merely pits in the earth with spur tracks leading up from the main line. Most of the bombardment was conducted from this position; that is, from March 23 to May 1 and from August 5 to August 9. The emplacements at this position were in process of leisurely preparation for nearly three-quarters of a year before March 23, when the bombardment began. The preparation of these positions with their exact locations with respect to nearby roads, railways, etc., as shown on military maps was reported by French peasants through Belgium to Paris long before the bombardment began, but without any knowledge as to the purpose of the positions. The knowledge of the exact locations of these emplacements, however, together with the approximate location of the source of the bombardment by sound ranging, made it possible for the French army to open up counter battery fire just 30 hours after the first shot was fired by the Germans. This position was 12 kilometers from the front lines at the time the bombardment began, and the Germans had not supposed that they would be so quickly located.

"It was at first an enigma to us how the French had managed to locate the exact positions of our guns 30 hours after the first shot had been fired. . . . The battery commander hit upon the solution of the enigma when he said, 'We have been working on the construction of these positions for three-quarters of a year. Frenchmen whose liberty to come and go is practically unrestricted . . . are living all around us. I am certain that the exact position of the big battery emplacements was long ago communicated to the French Army Command via Belgium, as has so often been the case. The only thing they did not know was what was going to be done with them. They therefore had guns in readiness for action as soon as anything special happened.' . . . By the middle of March, 1918, the battery whose position we had selected a long time before was ready at Laon. It consisted of three gun positions well concealed in a timber forest. . . . There were block houses for the officers and naval gunners to live in. . . . There were chambers five meters underground for storing the ammunition, and battle headquarters above ground and battle headquarters underground, which latter no one thought of using at the time, the foremost enemy lines being still about 12 kilometers away. A large area was provided with smoke cloud apparatus for screening the guns from observation by enemy aviators and captive balloons when firing in clear weather. Solidly built tele-

phone lines connected all conceivable positions with main battle headquarters." (9)

"Ammunition shelters and dugouts for personnel were constructed in the side of the hill at the β and γ positions; they were deep and spacious, but of ordinary type so well known on the front. At the α position, which was level, two concrete shelters with massive concrete tops more than 4 feet thick were placed somewhat in rear and on the flanks of the platform. The camouflage for each position was a large wire net with usual leaf, twig, and grass covering. Its weight was such that a large number of men must have been required to manipulate it. The trees on the lower side of one emplacement had ladder cleats nailed on up to a height of about 30 feet, evidently to be used by the detachment handling the camouflage net, by each man having a cord attached to the edge of the net. The trees around the platform were cut as little as possible and the epi where it crossed a field was covered with earth so that only the top of the rails showed." (3)

The second position, near the village of Ham, was used apparently during the period of May 27 to June 11, and it was from this position that the 240-millimeter projectiles were received. The third position, near Fere, where possibly the steel platforms were used for the first time, was used during only two days, that is, July 15 and 16, for the firing of only 14 projectiles. The gun and carriage was then hastily withdrawn to the first position, where it was operated continuously from August 5 to August 9.

The Bombardment from the German Side

Some time before the gun or guns were moved to the firing positions the base plate, or at least the azimuth rings, were marked with the direction of the particular point in Paris on which the guns would be laid. An error of one degree in laying the gun for direction would cause a deviation of 2,000 meters or 6,480 feet in Paris. An error of a single minute would cause a deviation of 100 feet.

"It was therefore necessary to provide the bed plates with the most accurate of markings, the zero position of which was directed at a given point in Paris. The difficulty was overcome with ease. A Saxon professor of geography measured trigonometrically all three bed plates for us within two days." (9)

Apparently the entire crew which operated the guns was supplied from the Navy, but clothed in Army uniform.

"The whole affair was not very agreeable to the Army in whose zone we placed the guns. It knew neither the guns nor the crews, but had nevertheless received orders to comply with our wishes and assist us. The assumption was naturally that a violent counter action on the part of the French would be the result in case the bombardment of Paris were effective. It was the Army's task to repel this, and furthermore, if we were able to fire our long guns without taking special precautions, even if the aviators and captive balloons observed nothing, they would ascertain the positions of our guns in a few days by means of the system of sound-ranging instruments. We wanted to avoid this as long as possible, and that demanded special measures on the part of the Army.

"We had therefore adopted the following precautionary measure: isolated guns of similar caliber were placed at intervals of a few kilometers and their commanders connected with our battery by telephone. They ranged on any targets at short distances of from 22 to 25 kilometers and were to fire simultaneously with us upon a telephonic order. It might be assumed that this procedure would make it very difficult for the enemy's sound-ranging sections to locate the Paris guns. This plan was carried out. It demanded keeping in close touch with the Army artillery command, so that all guns should be ready for simultaneous fire at the given time despite any breakdown. This undoubtedly meant a great curtailment of the independence of the artillery commanders." (9)

"I believed that observation of the first few shots would be sufficient. Our best aviators enthusiastically placed themselves at our disposal for observing the hits on Paris. We decided, however, to bombard Paris . . . without observation. We believed that the French themselves would attend to the report from the targets and without any delay whatsoever.

"At 10 p. m. on March 20 the artillery general at Marle informed us that a heavy bombardment would begin at 4 the next day, that is, March 21. . . . On the 22nd we received orders to open fire on Paris the following morning. The first shot was fired at 7.15 a. m. on the 23rd and then every quarter of an hour, then more frequently until the sun broke through the clouds at 2 p. m. and we stopped, so as not unnecessarily to betray the presence of the batteries for the French captive balloons were hanging in the sky on all sides of the horizon and searching the country.

"Fire was continued the next morning in the same way as it had been begun. For the present two guns were firing on Paris, their average points of impact probably being about 1½ kilometers apart. . . . The enthusiasm which officers and men had in handling this extraordinary apparatus began to wane under the influence of the uncertainty of the effect." (9)

"We had paid agents in Paris who had instructions to send us a report at the first possible moment. On the evening of the first day we received a telegram saying that all of the shells had landed in Paris. A couple of days later we received a written report and a map of the city showing exactly where each shell had struck." (7)

"A telephone call from the Army High Command was reported at 1 p. m. (apparently on the second day) stating that Paris morning newspapers reported bombardment of Paris by heavy guns in a position at present unknown. Immediate communication of this telegram to the gun crew called forth great rejoicing among them. The satisfaction at seeing the protracted and difficult task crowned with success was great at our battle headquarters. . . . Glasses were set at dinner, which was partaken of by watches, that is, in two detachments, one-half directing the fire. The glasses had just been filled a second time when a shell of the heaviest kind fell on a meadow in the middle of the whole battery position and 250 meters from battle headquarters. A moment or two afterwards there was a second only a few hundred meters away from the first. There was no doubt that the location of our position was known and being bombarded by heavy artillery.

"In the meantime our two guns continued to fire unconcernedly. The third was not yet ready and did not come into action until several days later. We had rapidly arranged a very effective alarm system. One of our antiaircraft batteries was installed about 4 kilometers away in the direction of the enemy guns which were bombarding us. They heard the shells flying overhead and passed the word by telephone to battle headquarters, which immediately passed it on to the guns. This left about three seconds before the explosion, long enough for the men at the guns to throw themselves down in the most sheltered positions behind the guns. In this manner the counter action which became extremely violent during the first days disturbed us but little. The enemy's

ammunition was very poor, especially at first. They used base fuze shells which penetrated deep into the ground and blew enormous quantities of earth into the air. If anyone was standing 20 meters from the explosion he was of course knocked down by air pressure and covered with earth, but generally remained uninjured and quite fit for duty. None of our guns was hit. Losses were very slight, although more than 5,000 heavy shells were fired on the positions during the first fortnight. On one day alone we received about 700 heavy shells within ten hours. On the first day of the enemy bombardment a heavy shell exploded against a big tree and the splinters severely wounded six men, including an officer serving as the gun commander. The bombardment of over 5,000 shells cost our battery the loss of seven dead and thirteen wounded, but no damage to matériel." (9)

"It was very interesting to find craters made by 305, 320 and 340 guns in destruction firing and to identify certain craters that were easily seen on the air photographs taken just after firing. These heavy projectiles were fired from the valley of the Aisne near Soissons at a range of about 30 kilometers. Their detonations must have been very severe on the nerves of the German personnel, as must have been also the harassing and interdiction fire of a French battery of 145 millimeter 'Schneider Longue' guns emplaced for this purpose just in rear of the French line." (3)

The French railway guns used in this bombardment were located at Vailly.

"Confirmation of the manner in which the French located our batteries was obtained from French papers captured at the taking of the Vailly-LaFere-Noyon corner and the French railway guns at Vailly, which, on the whole, made things pretty warm for us. Among the artillery plans captured was one on which the positions of our Paris guns were marked with geographical accuracy, just as they stood in the woods. Lines of intersection had moreover been drawn by a lieutenant of a French flash-ranging section who, in his accompanying report, alleged that he had ascertained the position of the guns by means of drawing lines through the smoke arising from the smoke generators. The latter, however, were about 1,000 meters away from the guns, whereas the lines of intersection drawn from the positions of the French flash-ranging section intersected exactly (within ten meters) at the emplacement of the gun indicated. Thus he had previously known the exact position of the emplacements and had drawn his lines of intersection in accordance, with the smoke generators as an afterthought." (9)

"When the great gain of terrain after the March offensive was assured, it became an urgent necessity for our battery to follow as speedily as possible. We got to the neighborhood of Ham, almost twenty kilometers closer to Paris. This resulted in a great increase in the life of the guns and had to be taken advantage of under all circumstances. This entailed the construction of new emplacements at Ham and a change of position as soon as possible. This naturally resulted in a short pause in firing, due to transportation. In the interval the French were boasting that they had put our long-range guns out of action, and it was being anxiously asked at home why we were no longer bombarding Paris.

"In May, 1918, when the armies of the Crown Prince were making their brilliant push across the Chemin-des-Dames, which with but slight losses, took them much further forward than had been planned, the long range guns were continuing to bombard Paris from the vicinity of Ham at a distance of about 110 kilometers. They were very much harassed by aviators and molested especially at night but suffered no losses worth mentioning.

"Another opportunity then presented itself to strike a harder blow at the enemy Capital and thus make more use of the capabilities of the guns. A new position was sought out and chosen without delay and everything was sent via Soissons into the sinister triangle, Soissons-Chateau Thierry-Rheims, which had only a single railway line for the entire supply of troops, equipment, ammunition and rations.

"As soon as the position there was prepared and the gun emplaced I went south via Vailly and Fismes to

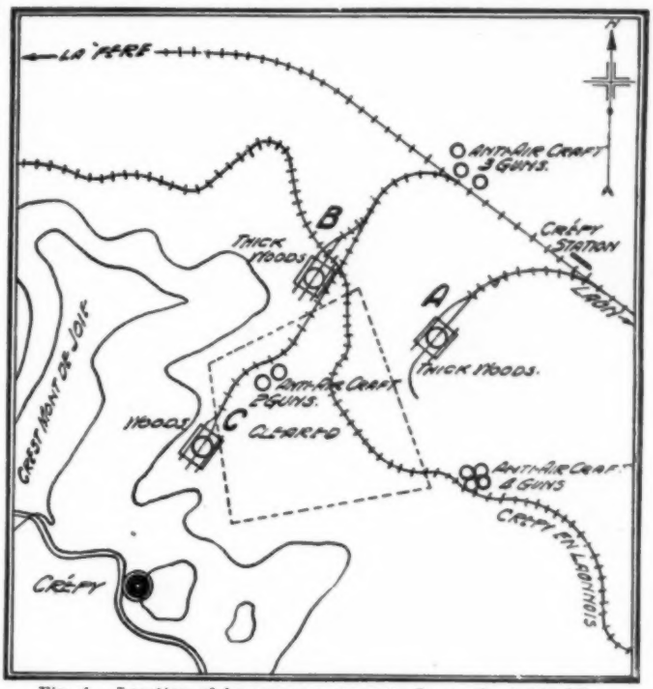


Fig. 4. Location of long-range guns near Laon, about 122 kilometers from Paris

Fere-en-Tardenois which was under enemy fire. Twenty minutes more and I was at the farm which had been assigned to the special Naval Command. Some comrades were there also and away we went into the woods. Everything was ready for action. I had the firing order in my pocket. I made a brief inspection of the position and we began firing immediately. Things went like clock-work. We stopped at dusk.

"Any sort of rest at night was out of the question. The anti-aircraft guns roared the whole night, swarms of enemy motors hummed above and bombs tore through the air and crashed right and left, in front and behind. There was no change next morning. The enemy aviators came over in squadrons of twenty and twenty-four. Only a few Germans went out to meet them. . . . As soon as the air above us was tolerably clear of aviators, the muzzle of our gun was raised and a shot peppered on Paris.

"We saw two days later that we should have to evacuate the position of the Paris guns, and proceed by way of Soissons, because at that city was situated the only turn-table by means of which we could get out of the sinister triangle south of the Chemin. Things looked ugly at Soissons, and we could not tell how long it could be held against the disproportionate superiority. . . . In spite of all difficulties, my comrade who was in charge of the command actually got the gun through Soissons and to the rear position. The enemy thus never saw one of these guns. With hearts filled with rage and shame,

we at last had to destroy these marvels of military ability and brilliant technical knowledge in our own Fatherland." (9)

The Bombardme... from the French Side

At 7:15 on the morning of March 23, 1918, just two days after the Germans opened their offensive against the British Fifth Army before Amiens, the people of Paris were startled by an explosion of something that had fallen on the Quai de Seine. The explosion was of such magnitude that it could be heard over practically the whole of Paris. Fifteen minutes later there was another explosion of the same magnitude, but this time closer to the

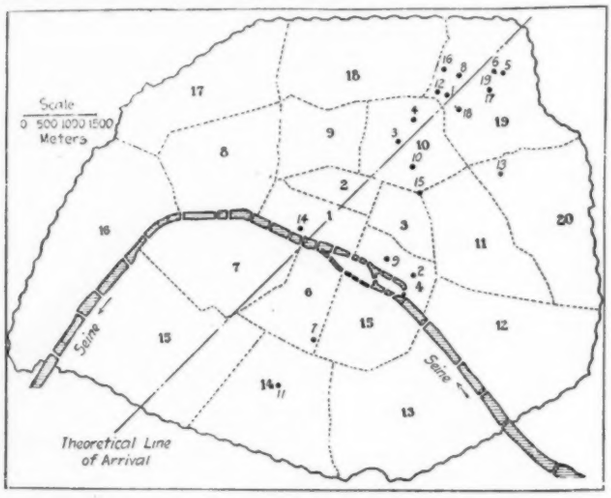


Fig. 5. Map of the City of Paris showing points of bursts on first day of long range bombardment (March 23, 1918), in the order of their arrival

Seine, on the Rue Charles V; fifteen minutes later another explosion occurred on the Boulevard de Strasbourg near the Gare de l'Est. Until that time Paris had never been bombarded except from airplanes and Zeppelins, and the first thought of the people was that they were being bombarded from some new type of aircraft that was being operated at such a height that it was practically invisible.

The explosions continued to occur throughout the morning at very uniform intervals of 15 minutes, and by 2 p. m. twenty-one explosions had occurred at the places shown in Figure 5. After the first few explosions, between seven and eight o'clock in the morning, business in Paris practically ceased. Stores were closed and part of the Metro system ceased to operate; ticket offices in some of the railway stations were closed, and great numbers of people could be seen walking the streets looking skyward trying to locate the planes that were dropping the supposed bombs.

By the end of the first day officers of the French, as well as the American, armies were quite certain that the projectiles were being fired from a newly designed long-range gun located within the German lines, and operating at a probable range of 110 kilometers (68.8 miles).

During the next few days some interesting theories were advanced in the various newspapers. In one case it was maintained that the projectiles which arrived in Paris were being fired from another much larger projectile, which actually served as a gun. This larger projectile was said to have been fired from a gun within the German lines, and upon attaining a certain height a charge of powder within the larger projectile was automatically ignited, firing the smaller one to a much greater distance. The theory that the projectiles were being fired from guns concealed in abandoned quarries or in heavily wooded regions near Paris received considerable credence, and diligent search was made of all such places to be certain that it was not true. A third theory was that the projectiles were being fired from a pneumatic gun located within Paris.

A plotting of all the bursts for the first day showed results that were very puzzling. If the guns were being operated at comparatively short distances, the only way to account for the tremendous dispersion was on a basis of actual laying of the gun for different objectives. This theory did not seem plausible, however, because if the gun was actually laid on given objectives, these objectives were of relatively small importance. If, on the other hand, the projectiles were being fired from a gun at a great distance, it was seen at once that the dispersion was so great as to make it practically impossible to hit with any certainty any objective much smaller than that portion of Paris within the walls. It was noticed that the dispersion in direction, that is, to the right or to the left of the line on which the projectiles were arriving, was comparatively small, while the dispersion in range, that is, over or under the probable point at which the projectiles were supposed to arrive, was very great. Examination of Figure 5 shows that on the first day, when the gun was new, the average dispersion in range was very small compared with the dispersion on later days when the gun became worn.

"The French kept records during the fire of these guns as follows: at the front by all observers who could see or hear from any point the date, hour and minute of every round. In Paris all policemen near the point of fall of a projectile had orders to record the date, hour, and minute of explosion, to go at once to the spot, find and collect all fragments possible, taking them by force if necessary from souvenir hunters. All such records and fragments were immediately turned over to the Technical Section of the Artillery. Civil officials of Communes in the vicinity of Paris were required to go through the same procedure whenever possible as to date, and so forth, for projectiles falling outside of the city. By painstaking study of these records and fragments the time of flight from Mont de Joie to Paris was soon determined to be about three minutes." (3)

The writer's first direct acquaintance with the bombardment was during the third and fifth days. With considerable surprise it was observed that already the people were taking it quite philosophically; in fact, it could not be seen that they were paying much attention to it at all. At intervals of about fifteen minutes muffled explosions would be heard in different parts of the city, seldom two consecutive explosions in the same vicinity. Many people would stop for an instant and attempt to decide from what direction the sound had come, after which they would go on their way apparently unconcerned. It was, of course, still sufficiently novel to be of considerable interest and people were talking about it everywhere.

"The French took measures almost at once to combat the long-range guns and protect Paris as far as possible. Briefly, the plan was to harass by the 145's whenever the Paris guns opened and to fire for destruction whenever conditions were favorable for airplane observation. To protect these batteries from counter-battery and neutralization fire of hostile batteries it was necessary to emplace enough medium caliber guns to occupy all German batteries in the area and keep their fire down. The success of this plan was marked. The destruction fire by heavy

calibers had much more moral than material effect. The evidences of the harassing fire were numerous and the personnel must have been kept in dugouts most of the time. This 145 battery was so well protected by the counter battery neutralization that although only two kilometers in the rear of the French first line trenches, it never lost a man nor a gun damaged between the time of its emplacement and May 27 (when it was withdrawn) and it was effective in minimizing the fire on Paris. Direct telephone connection was already established between Paris and the Groupment commander so that whenever Paris reported a projectile as having arrived it was only a few minutes before the Germans would receive a violent bombardment in reply." (3)

The table on page 169 gives the bombardment by days during the entire period and shows the number of projectiles falling within and without the walls of Paris each day, and the number of people killed and wounded. Data published in *L'Illustration* referred to under reference No. 2 (see Part I of this article, page 98, ARMY ORDNANCE, No. 20, September-October, 1923) lists in addition the exact location of the fall of each of these 303 projectiles by the intersection of the nearest streets. During the first few days of the bombardment the first projectiles arrived between 7 and 8 o'clock in the morning and continued to fall generally at regular intervals throughout a portion of the day. On some of the later days the bombardment would begin at 12.40 noon. It is interesting that the time of the beginning of the bombardment seemed generally to be known. It was interesting to observe particularly on those days when the bombardment would begin at 12.40 noon that people would be standing about holding their watches from about 12.35 on waiting to see if the first projectile would arrive on time. The table shows three long periods, that is, from May 1 to May 27, June 11 to July 15, and July 16 to August 5 in which no shots were fired. During the first of these periods the French people were quite certain that their guns had put the long-range guns out of commission. Actually the Germans were transferring their positions to the vicinity of Ham. Not much account was taken of the second interval because the German drive had brought the armies down to the Marne and the impending next drive seemed so certain of breaking through and probably enveloping Paris that few gave any thought to the long gun. During this period the long guns were being transferred down to the Marne salient where one of them was operated for two days only. Very little account was taken of the last period because during this time the Allied armies had taken the offensive and were progressing so satisfactorily that again the bombardment of the city was of minor consideration. During this period the German gun was being transferred back to its first position, from which it operated on five successive days. The Germans indulged in night firing on only four occasions. The last projectile of the entire bombardment fell between 1 and 2 o'clock on August 9. Already the Allies in their successful drive north of the Marne, between Soissons and Rheims, were driving the Germans back so rapidly and had made such progress as to put the long-range guns in serious danger. Figure 6 shows the location of all of the bursts within the walls of the city, a total of 183. One hundred and twenty more fell outside of the city, making a total of 303, 55 of which were of 240-millimeter caliber and arrived on the five days, May 27 to May 31, from the position at Ham.

Effect

It is quite probable that the regularity with which the projectiles were arriving got on the nerves of some people, and that the bombardment was responsible for the departure of some of those who were crowding the trains west and south from Paris. It seems more certain, however, that by the first of June the close proximity of the Germans to the city of Paris, together with the anxiety caused by another drive impending, added to the effect of the heavy bombardments from airplanes on every clear night, had far more effect than the gun. The visible destruction of property was so slight as to give little evidence to any one traveling about the city that the explosions they were hearing from time to time amounted to anything. The newspapers were very careful to avoid any discussion or even a lengthy reference to the bombardment from day to day, and neither gave the locations of the places where the projectiles had fallen nor the number of killed or wounded.

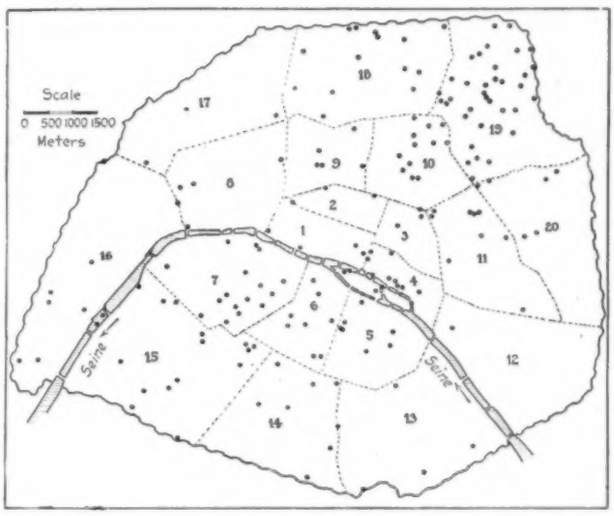


Fig. 6. Map of the City of Paris showing points of bursts of the 183 projectiles that fell during 44 days of bombardment

Except in a few places where the damage was so exposed as to attract attention, no matter how slight it might be, there was little evidence that the bombardment had any effect. On March 29, the day on which the second gun began to fire, and fired only four projectiles, the one projectile which landed within the city of Paris struck and knocked out the keystone in one of the arches in the roof of the church of St. Gervais near the Hotel de Ville. The falling of the keystone caused a large part of the arch and the roof to collapse, and most unfortunately the church was quite full of people at the time. Examination of the table on page 169 shows that this day holds the record for casualties. On one other occasion a projectile burst in the lobby of a hotel, killing a number of people but doing comparatively little in the way of material damage. Ordinarily an explosion would make only a comparatively small hole in the ground. The average casualties per projectile was one killed and two wounded.

"The normal effect on the inhabitants of Paris was to cause an exodus of the timid into the country south and west of the capital, and probably between half a million and a million did leave the city for several months, giving a basis for the German report in the Orient that Paris was being depopulated by the bombardment. This diminution of the population at this time was an advantage as the provisioning of the remainder in the cap-

ital was thereby simplified and those who scattered into the country were also much more easily subsisted. The laborers in munition factories and other war work stuck to their posts and the flow of war material was not sensibly diminished." (3)

Fate of the Guns

It was specified as one of the terms of the Peace Treaty that one of these guns should be turned over to the Allies in perfect condition. This term was never complied with and according to the only information available all of the seven guns constructed were destroyed within a period of a year.

"Three of the seven guns, tubes numbers 16 to 18, were at the front when the German army began its great retreat in 1918. When, as a result of this retreat and of the too great distance from Paris, the continued use of the long-range guns was no longer possible, the four tubes which were at that time in the factories being finished were destroyed. Of these four cannon tubes numbers 12 and 13 were completely cut to pieces and the material was either utilized for other cannon or melted up. Tubes numbers 14 and 15 were cut up and the inner tubes so damaged that they no longer could be termed long-range guns. Later these tubes together with tube number 18 mentioned below were sold to the firm of Herman Tilger in Oberhausen and melted up by this firm in October and November, 1918, and the iron returned to Oberhausen. After the armistice there were therefore in existence only the three tubes which had been used at the front, numbers 16 to 18. When, at the end of April, 1919, the occupation of the Ruhr district seemed imminent, the inner tube of number 18 was cut in two. This work, due to the lack of time, could not be carred out with tubes numbers 16 and 17. Tube number 16, therefore, still complete, was sent to the Marine Testing Ground at Altenwald, near Cuxhaven, and tube number 17 to the Gruson Works at Magdeburg. Tube number 16 was then sent from Altenwald to Meppen and was there blown up in the presence of a representative of the German Admiralty. Tube number 17 was cut to pieces on November 22, 1919, in the Gruson Works, also under the supervision of the German Admiralty. The material obtained from the two tubes was then sent to the firm of Krupp at Essen and after further cutting up was there melted." (10)

Value

The Germans must certainly have known that their gun was not a profitable investment for the destruction of property, hence they must have continud the bombardment purely for its destructive effect on the morale of the Parisians and its beneficial effect on the morale of the Germans. It is certain now that they could ill afford to use their manufacturing facilities for the making of such guns as these at a time when they were so desperately in need of heavy field guns to assist their armies in their big drives. In his book, "My Thoughts and Actions," General Ludendorff says: "During the battle we had commenced bombarding Paris from near Laon with a gun having a range of 75 miles. This gun was a marvelous product of technical skill and science; a masterpiece of the firm of Krupp and its director, Rausenberger. The bombardment made a great impression on Paris, and on all France. Part of the population left the capital and so increased the alarm caused by our successes."

"Despite the manner in which the technical difficulties were overcome in building a gun of this unprecedented range, it must still be regarded merely as an experiment *which is chiefly useful as indicating the lines along which low trajectory guns can still be improved and what obstacles are still to be overcome.* It would be interesting to investigate further the question whether long caliber guns of extreme range really have military value. A condition precedent is that all of the weaknesses of the long gun which we used against Paris shall be overcome. If this can be done such guns will be of extraordinary value, especially for battles on the high seas, for coast defenses, and defenses of fortresses.*

"In addition to the scientific construction of the gun and projectile and the quality of the powder, a main requisite is an extraordinary highly developed steel industry. England and France have not such an industry and their fear of the German efficiency led them to provide in the Peace Treaty that nothing larger than short barreled 28-centimeter cannon may be manufactured in Germany, and so we cannot carry on our experiments." (7)

Progress in science and in engineering is always made by attempting the unattained or the apparently unattainable. Automobile companies find no direct commercial profit in the manufacture of racing automobiles. On the other hand, were it not for the fact that each of them makes racing automobiles capable of a speed of 100 miles per hour or more, there would not be in existence today in the world the millions of well-designed and efficient operating automobiles which sell at such reasonable prices. It was only through solving the problems with reference to carburetors, engines, transmission bearings, lubrication, etc., for racing cars to be driven at from twice or three times the normal speed of the commercial car that engineers learned sufficient about these various mechanisms to design similar mechanisms for the commercial cars which we buy. When an engineer has mastered the problems involved in designing a carburetor for an engine which is to drive a car at 100 miles per hour or an airplane at 200 miles per hour, he has become so much a master of the problems of that particular mechanism that the carburetor for the 30 to 50-mile commercial car is designed with ease and to a high degree of efficiency.

In spite of the fact that we have been using guns for seven centuries there really has been comparatively little research work devoted to their development as compared with that devoted to the development of such commercial machines as the locomotive, airplane and automobile. What we do not know about the action of the projectile in the gun, the characteristics of the various types of wear of guns, the real reasons why the various parts of a gun wear out, the rates at which guns of various calibers, velocities, and materials wear, and the effect upon the flight of the projectiles of all of these types of wear in their various stages is so overwhelming that the organization of the research to solve these problems is staggering. We depend upon our guns to protect us in time of emergency and yet we are nationally content to gamble that protection frequently on guns as antique as an automobile of twenty years ago. Commercial organizations cannot be interested in solving such problems in spite of the fact that a cannon is actually an internal combustion engine. It is therefore profitable for any nation to devote millions of dollars to the construction of a few such weapons simply in order that we may thereby the more intelligently and certainly design the ordinary field and seacoast cannon which are our insurance and protection.

Author's Note.—This statement is to be taken with considerable qualification. Even the largest battleships are excessively small targets at such ranges and only hits count.—H. W. M.

Artillery Ammunition

By

R. L. AVERY

WHEN we stop to consider the great number of guns in use along the Western Front at the end of the War, the question comes up not only as to how the ammunition was supplied to the troops, but also how it was obtained, manufactured, stored and delivered.

It is evident that in order to properly supply ammunition to the firing batteries an extensive program must be laid down and be backed up by a going organization. It is with this problem of supply of ammunition that this paper will deal.

In general, peace-time development of any munition is carried on by experiments with the best on hand and making whatever improvements on it that can be made, using as a basis for the effort the necessity of producing something better and more efficient. There are two general sources from which a start may be made in developing ammunition, the first is to improve our own, the second is to take the best foreign product and attempt to improve it. Once a design or an improved design is laid down, it must be approved before it can be put into production. Approval of a design should be thoroughly thought out before final acceptance, as more often than is realized a change in ammunition necessitates far-reaching changes in accompanying matériel, which may, taken as a whole, tend to make undesirable the acceptance of the new design. As a concrete example, let us take such a case as this: there has been proposed and manufactured a caseless cartridge for small arms, the smokeless powder being in a cake and stuck fast to the bullet at one end and having incorporated in its other end the percussion primer. If stable and meeting the requirements of service conditions, the advantages of such a cartridge are at once evident—it is cheaper than the present brass cartridge, it is lighter, it is smaller, and therefore can be more easily handled and carried. On the contrary if this cartridge were approved for manufacture and issue it would necessitate the rechambering of every Springfield rifle in our service and the redesigning of all our machine guns. Considering the present number of rifles in use and in storage, and also the present number of machine guns already manufactured, the question of whether or not it would be wise to approve this new cartridge becomes one for discussion. Although eventually a caseless cartridge may be universally used, its adoption in our service at present would be prohibitive from the expense standpoint alone. This case is not cited as a possible curb to development, but as showing what in an extreme case may be the result of an advanced idea.

As a result of the World War the ordnance engineers of all countries are busy at present studying all previous designs of ammunition with a view to improvement. New types for different calibers have been laid down, and should we again find ourselves at war we should immediately discover that there were new types with which we were not familiar. It is imperative that we keep abreast of the times, not only with improvements in our own present stocks, but also with an eye to what other nations are doing, so that when the next emergency arises we shall not find ourselves wanting. Such a position would leave the Ordnance Department without defense in the eyes of the people of the United States. With our present knowledge of the ammunition in use by our various Allies at the time of the Armistice, we should be able to keep up with possible future enemies, so that in an eventuality we may not be found without the best means of defense and offense.

The responsibility of keeping the ammunition of the artillery up to date rests with the Ammunition Division of the Ordnance Department. The immediate responsibility for the development of ammunition rests on the different officers of the Ammunition Division. It should be their constant business to see that experimental and research work is carried on and that sufficient funds and impetus are supplied to keep peace-time development active. The combatant branches of the army should be freely consulted as to suggestions or improvements. Ideas submitted by enthusiastic juniors of these branches should be courteously considered and investigated.

With respect to artillery ammunition, it is the writer's opinion that the closest relationship should be maintained with officers of the artillery branches, in order that their desires may be known and their cooperation obtained in the trial of new ideas derived from whatever sources.

As to the actual development work after a design has been approved, this must in time of peace rest with some government activity, preferably some arsenal. We cannot expect industrial concerns to interest themselves in the development of ammunition in times of peace when their activities are along other lines and their profits derived from other sources.

It is therefore the business of the Ordnance Department to have the designs ready when the emergency arises, to be ready to throw the scheme of supply into production without delay, and to have its personnel and plants lined up in order that there may be no delay in getting the supply program started.

Had it not been for the ability of the commercial plants of this country to quickly adapt themselves to our needs in the late war, the production of ammunition could never have been what it was. We profited by the fact that before we entered the war we had the manufacturing experience of our Allies to help us. In bringing our own models up to date, and in laying down new models of ammunition, we also profited by their pre-war and early war development.

Another war would probably not find us in such fortunate circumstances, as we should probably have to be dependent on ourselves from the start. It, therefore, is quite important that we keep an eye on the peace-time development of possible new types of artillery ammunition and of ammunition in general.

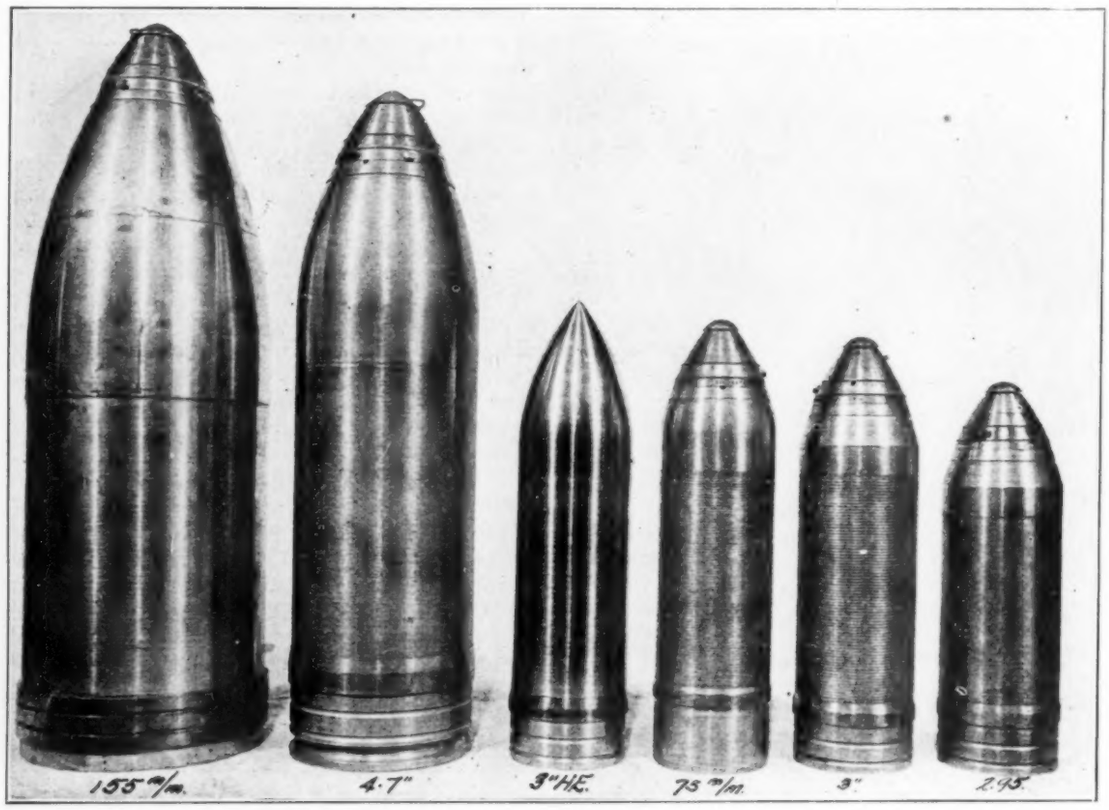
The peace-time plan with respect to the manufacture of ammunition should be formulated in the office of the Secretary of War. Any plan for the replacement or manufacture of new stores for war purposes must be dependent on the appropriations made for such purposes by Congress,

and so its success is problematical. Concerning any plan for replacement of stores such as munitions, it might be said that if such a plan for replacement is not made and put into effect the ammunition now on hand will in the next fifteen or twenty years become unfit for use, and we shall find ourselves at the outbreak of another war without an adequate supply and therefore unprepared.

To carry on the program of replacement the present plan should be to use the manufacturing facilities of the pre-war arsenals. These arsenals, while not as large as some of the war-time plants, are still large enough to carry on a process of replacement. Each arsenal naturally specializes along some particular line of production and has a group of dependable and experienced workmen, who, through their training both before and during the last war, are able to satisfactorily manufacture the necessary replacement stores.

After the war the Government found itself in possession of many manufacturing plants. These plants were of large capacity and were not suitable for experimental and small development work. They were expensive to run and were in general of temporary construction so far as the buildings were concerned. As a peace-time measure it was, therefore, wisely determined to close them down as rapidly as possible, sell those which were thought to have no immedate military value, and keep the others in reserve. With this policy in view, and because of the reasons given below, the activity in peace-time production was to be centered at the permanent arsenals. The reasons for deciding on the permanent arsenals for experimental and development work might be briefly stated as follows: the permanence of construction at the old arsenals, their permanent transportation facilities, and their working organizations. In general they were situated near a permanent source of labor and they could probably be more economically operated than could the war-time plants.

In connection with the peace-time production of ammunition comes the problem of the storage, supply, and maintenance of such ammunition. In any system of supply of military stores the supplies must always be put as near the using troops as possible. In time of war supplies are placed as near the front as possible by the supply departments. In time of peace the proper storage points for the various war stores must be pre-determined. The question of the geographical location of such storage places must be determined by the General Staff, with a view to placing the stores in the most accessible place, taking into consideration generally the front or fronts from which we are liable to attack or from which we must make an offensive.



Exterior views of U. S. Artillery Ammunition

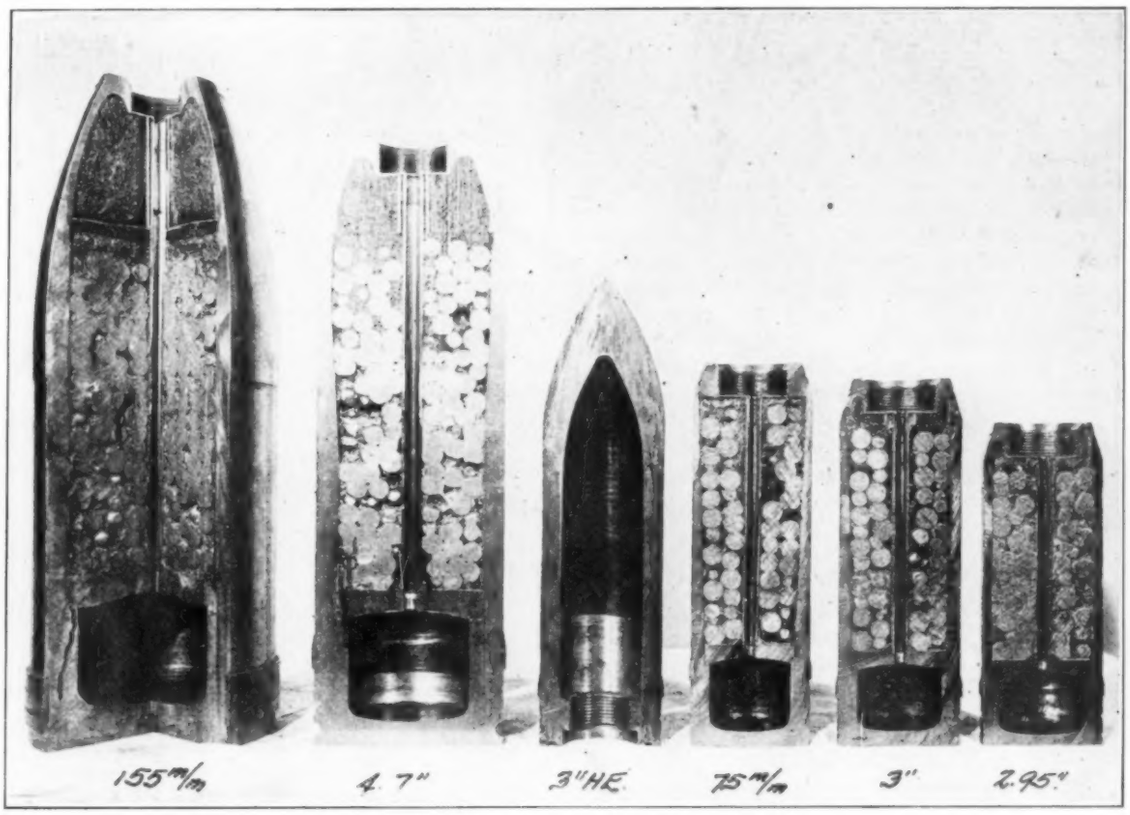
At the end of the war this country found itself in possession of large quantities of ammunition already made or being made. With the completion of that under manufacture, and with the demand cut off, our supply was enormous. Much of this ammunition was of an inferior grade and is being salvaged and broken up into its components, much is being overhauled, and due to the expense of transportation this is usually done at the point where the ammunition is in permanent storage, and much more will require overhauling during the next few years, as inspection shows that it is becoming unstable, unfit for use, unsafe to handle and unsafe to fire—in other words useless as an offensive tool and dangerous to ourselves.

It is believed that these war stocks will be satisfactory for our natural needs, provided no new emergency arises, for the next decade, but we should start a program of replacement which, lasting over a suitable number of years, should completely replace our present stocks. The accept-

ance of such a plan is problematical. It is dependent on the factor of a continuing policy within the War Department, and we can hardly look back to a period of approximately ten years and see much continuity of effort covering so long a period. This scheme of replacement is also contingent on no war during the next ten years. While such a state is to be hoped for it can hardly be assured. This policy of replacement is the only sane one which can be laid down, due to the varying factors of our national life.

In general, the time for development of ammunition is previous to war, not during war. To be prepared a country must have made its studies previous to the beginning of hostilities, in order that it may know exactly what is wanted when hostilities commence. However well prepared a country may be, certain war-time developments must be made, as new types peculiar to different tactics employed in each succeeding war, and peculiar to new conditions and implements devised by the enemy, will always come to the fore. When the Allies went to war with Germany in 1914 it is believed that the Germans were the better prepared as to all technical programs. They were reasonably up to the minute in their munitions. However, before the war had advanced to any great extent each contestant found himself facing new conditions and requiring new implements. The trench mortar in its various calibers, the gas shell, and the tank, are all products of the recent war and are very important.

Immediately on the outbreak of war there should be established in this country, at a suitable arsenal where experimental facilities are already installed, an experimental and development station set up to handle nothing but experimental and development work. New devices of whatever nature obtained at the front should be immediately sent back to this station for investigation and possible improvement. The particular mission of this experimental and development station should be for these purposes only. Experimental stations are a war necessity and should be fairly in readiness before the outbreak of hostilities. They are really as much a peace-time project as is the training of the field army in time of peace. To go a little more into detail, certain sections of different arsenals should be set aside for experimental and development work, and these sections should be properly organized both as to personnel and material. These sections should follow logical and definite lines of investigation during peace time, using the best information obtainable at home and from military sources abroad. The efforts of these sections should be to keep abreast of the times, to keep up with the development of the other nations, and to know what "the other fellow" is doing. In times of war they should be capable of quick expansion and should be thoroughly prepared to handle war-time development work. Perhaps the most striking case of a surprise in the last war was the introduction of gas by the Germans. It can well be imagined what would have been the outcome of the use of gas had not the Allies been able to immediately investigate this new weapon and develop something at least as effective as a means of defense and offense.



Cross-section views of U. S. Artillery Ammunition

The war-time development of the last war was tremendous, the weapons with which all nations went to war becoming in many cases quite out of date in the four years duration of the war. So it is seen that in future wars war-time development must have its place, as it always has had in the past.

Wars are decided partly by the implements of war used, and there is no way of determining the effectiveness of a particular design after its arsenal tests but to try it out on the enemy.

At our entry into the late war, while we had plans for the mobilization of men, certain plans of defense for our coast, and certain plans for offensive tactical operations on file in Washington, we had few plans for the industrial mobilization necessary to put into production the many necessary implements of war. In a way we were aided by the fact that many plants in the United States were already making munitions, particularly ammunition for the Allies. However, with our advent into the war our problems of production were brought specifically home to the Government, and the problem of supply, which had previously been the Allies' problem, became ours. We were faced with the serious problem of equipping and furnishing ammunition for our troops as soon as they could be trained. It was fortunate that we did not have to get into the war at once, and that we could depend on the British and French to await our arrival. Had not this been the case our turmoil of preparation would have been many times greater than it actually was. Eventually we got into production, not at first through a thoroughly developed plan, but in a hit-or-miss style. With the close of the war certain detailed and well-thought-out plans were devised whereby we should not find ourselves wanting in this particular line of preparedness should another emergency arise.

Any plan which provides for the supply of munitions of war must be one that can go effectively into operation upon the event of hostilities. Any makeshift plan is of no avail for such a contingency.

A suitable production plan for war-time supply of munitions should have as its basis the following estimates: (*a*) Estimate of Requirements, (*b*) Estimate of Stocks, and (*c*) Production Capacity and Costs of Materials Needed.

With respect to artillery ammunition, as well as with respect to munitions in general, this estimate of requirements should provide that the ammunition, as estimated for by those drawing up the war plans, shall be available to the using troops at the place of consumption.

With respect to the statement of stocks, etc., in order that the Ordnance Department may know just where it stands, it should have available a statement of stocks suitable for making ammunition and available for that purpose and no other. This means that from time to time there must be compiled and forwarded to the necessary office a record of the available ammunition stocks of this country. With respect to production capacity, similar reports should be made. The production estimate should cover the cost of manufacture of the desired articles as well as the time required to finish the articles. If at any time the General Staff desires to know just how much they can be supported by the munitions plan a consultation of the stock records and rates of production should tell them.

The various estimates of what ammunition is desired and the time to make it having been determined, the next question is that of costs. Congress must make the necessary appropriations to cover the estimated costs, and no doubt it will do so in an emergency. What is vital for war-time production is to know just what plant can and will make just what component of ammunition, how fast it can be made, and whether it shall be assembled or shipped to a point of assembly.

In any scheme looking to the procurement of large quantities of ammunition, the controlling authority in Washington should have all commercial plants tabulated and properly lined up at all times, so that when an emergency arises plans and specifications, previously arranged, may be immediately sent out to each plant that is to produce a part or a whole of the partial program. These plans should be ready and up to date.

In order that the time of reorganization, necessary to commercial interests to change over from peace-time to war-time production, may not be lost, it should be so arranged that certain arsenals could start on an intensive production scale immediately on the outbreak of hostilities. Such plans should be prepared for the various manufacturing arsenals. These plans should be in a state of readiness and should include, in addition to the quantities and varieties of ammunition to be produced, lists showing the organization of the personnel, and, where possible, the names of the individuals who will have charge of the various branches of activity at the arsenals.

In case of emergency, the procurement efforts of the Ordnance Department should be decentralized rather than held by a central control in Washington. In order to carry out this policy the District Ordnance Offices throughout the country should be well established and as far as possible situated at the manufacturing centers. These District Offices should keep advised as to the capacities of the various plants in their districts, their stocks, etc., and they should keep the Ordnance Office in Washington informed of these capacities. Should occasion arise the District Offices should issue the necessary instructions to the plants within their districts to start on production schedules, as previously arranged. These District Offices, being properly located from a geographical standpoint, should be able to keep in better touch with their various commercial associates than could a centralized office in Washington, and in time of peace should constantly make industrial surveys with a view to keeping up to date the existing production programs.

As ammunition to be effective must be exact, sufficient inspections must be made of its components, both before and after manufacture, to assure the Ordnance Department that its finished products will meet specifications. In order to make sure that proper inspection of artillery ammunition is made in time of war, inspectors trained at the various arsenals should be capable of going out and acting as inspectors at the munitions plants which are engaged in the manufacture of parts or complete rounds. During peace time these inspectors should be constantly at work at the different arsenals on the inspection of the run of ammunition that is being made. They should be well versed in their duties and amply able to go out into commercial plants and superintend inspections for the Government. The permanent arsenals should be used as training schools for these inspectors. The different ammunition gages at the various arsenals and vantage points should be suitably catalogued and made available for issue immediately on the outbreak of hostilities and the beginning of production.

In order that the art of making munitions may not be lost, the Ordnance Department should manufacture at different arsenals sufficient ammunition to keep a nucleus of trained men together. The inspection of the product of these operations will keep the inspectors up to date and will keep the inspection force intact, which is very vital in time of war.

War-time inspection at its best has in the past been subject to much criticism, and too much stress cannot be laid on this phase of manufacture. A poor war product may be of vital interest to the national welfare.

Since the war, the Ordnance Department has centered a large amount of its development work on artillery ammunition and its accessories at Picatinny Arsenal; therefore, Picatinny is very definitely related to the ammunition problem.

The present layout of Picatinny Arsenal is an outgrowth of piecemeal effort rather than of an originally conceived plan. It has gradually grown up into what it is today by additions here and there. Originally laid out as a storage depot in a sparsely inhabited region unsuited to general farming purposes, it has become by the addition of different buildings from time to time an experimental and development center for artillery ammunition and its accessories. It is particularly suited for this purpose, as it is not large enough for production on any sizable scale and at its best could do but very little as a production plant.

At this arsenal in time of peace should be gathered the best minds in the development of ammunition, fuzes, powder, and pyrotechnics. Data obtained from technical investigations relating to explosives should also be deposited here. A suitable experienced force of technical investigators should be on duty for the purpose of experimenting with new designs and the improvement of old ones. Definite programs of investigation should be laid out and followed, particularly where we feel ourselves to be weakest in the way of competition with foreign governments. To this arsenal should be forwarded all military secrets, with respect to ammunition and explosives, gained by our Department of Military Intelligence. Here should be located a sufficient working force to keep alive the principles of making each one of the several propellants and explosives, to the end that this art be not lost when emergency shall demand that it be revived. In other words, this should be the experimental laboratory of the Ammunition Division of the Ordnance Department during time of peace, and the Ammunition Division should see that sufficient funds are forthcoming to carry out such experimental and development projects as are necessary to keep us abreast of foreign development. In time of peace it should not be forgotten that this arsenal is primarily for experimental rather than production work, and that at the present, except for the activities of some of the private powder manufacturers, no work is being done to assure the future of the various military explosives. The development of ammunition for artillery must not be stopped, as the field opened by the late war is very wide and Picatinny Arsenal is in a position to carry out all advisable experiments on the different types used and developed in the late war.

Component parts of a Mechanical Time Fuze

The war-time use of Picatinny Arsenal should be for two purposes, the first, development and instruction, and the second, production. Upon the declaration of war there should be called together at Picatinny representatives of the arsenal and representatives of the various companies who are able to properly manufacture and produce powder and explosives within a reasonable length of time. At this meeting the following should be explained to the representatives of these companies:—the purpose of the meeting, that is, to organize the powder and explosive production forces and get the whole on a working basis with the quickest results, namely, the supply of the product; the question of contracts, the form and general legal handling

of the letting of contracts; just what each company is expected to produce; the quantities and qualities of the products; the rate which each company is to reach as a matter of production; and when each product should be ready so that the complete schedules of production may be known to the Ordnance Office. The latter point is very important, that is, the time it will take to get into production, as powder and explosives are but two of the components of ammunition as a whole. In order that the metal components may be properly timed as to manufacture, so that the flow of completed rounds of whatever caliber may be uninterrupted once it is started and be at all times balanced, the proper ratio of production of parts of whatever nature should be made and known as soon as possible. It is very probable that even with this data secured in advance of hostilities a balanced schedule for production of components could not be made up, due to failure of some of the companies making either explosives or metal components to keep up to their quotas or to the ability of some to exceed their quotas.

In addition to the matter of schedules, which is believed to be the most important, there comes also the matter of inspections. As is well known, inspectors are always criticised severely, some for their lack of thoroughness in inspections, and some for their extremely strict methods. It should be the duty of Picatinny Arsenal to furnish the inspectors of powder and explosives made under the terms of these first contracts, and these inspectors should be trained in time of peace so that in time of war they would be immediately available.

Not only should Picatinny act as the first Government agent in securing powder and explosives, but it should also act as the Government agent in handling the details of the specifications for the purchase of shell, fuzes, shell cases, and in fact all metal components procured in the East.

Picatinny should be able to expand its peace-time activities to war-time purposes. As has been said before, Picatinny is one of the seats of experimental development of artillery ammunition and accessories during peace times. If Picatinny performs its functions properly during peace times it will have when war threatens a nucleus of trained men who will be able to go out and act as instructors and inspectors in all lines pertaining to the manufacture and procurement of ammunition. Since it is the plan of the Ordnance Office to handle procurement in the future through the different District Offices it is possible that Picatinny may furnish for these offices personnel of suitable qualifications to handle orders, contracts, inspections and payments. At this arsenal we have such a force, but were not this force greatly increased it is the belief of the writer that it would soon be frittered away. At present Picatinny has not the force to spread out from this center to any great extent. It might possibly act as a school for the instruction of clerks, inspectors and office personnel for the handling of the procurement of ammunition, but with its present force it is certain that if this arsenal were to go into production even on a small scale it could spare but very few of its present personnel.

With respect to the selection and training of personnel to carry on ordnance work, the writer believes a scheme similar to the following should be carried out: Officers selected for ordnance work should be graduates of the Military Academy or graduates of the better technical institutions of the country. The greater part of ordnance service requires technical effort, therefore the Ordnance Department should look to the source from which technical men may be secured. A proper standard of efficiency having been established for entrance into the department, and an officer entered, he should then, according to the views of the writer, be sent to duty with troops, and nominally but actually. He should preferably be sent to duty with the troops in the field, in order that he may see just what the using troops need, how they get it, where it comes from, and what they use it for. It may be argued that this is time lost from the ordnance standpoint, but it is believed that the short time lost in such training is more than made up by the general information gained by actual contact with the troops. In addition to the information gained by contact with the combatant branches, the officer detailed with them secures the much-needed rounding out required by the professional soldier. He gets to know what is expected of the officer, what the manner and conditions of the service are, and how his brother officer in the combatant branches does his work. The young Ordnance Officer can get this experience at no other place, and it is thought that time spent with the troops in the field is well worth the time that might reasonably be given to it. It has been the writer's observation that officers assigned to technical branches get to live too much to themselves, they get inbred, and they do not grasp the problem from the other side. The Ordnance Department is a staff branch, its purpose is to serve the troops, and it cannot serve the troops if it does not know what the troops want.

The length of the period which should be used for duty with the troops is one for argument. It is not thought that it should be less than one year for junior officers just commissioned in the Ordnance Department. After this year of service with troops it is believed that the junior officer should be detailed for a year to a manufacturing arsenal, in order that he may familiarize himself with the general routine and purpose of arsenals. The next year should be spent in school at Watertown Arsenal in practical shop work, largely touching on ordnance engineering.

Upon completion of the Watertown course each student officer should be assigned to some particular branch of ordnance, such as ammunition, light artillery, heavy artillery, small arms, aircraft armament, and sent to the particular manufacturing arsenal for that branch, where he should be given a refresher course of about three months covering in general the details of manufacture of the product of the arsenal. After this period of schooling he should be detailed to one of the manufacturing divisions of his arsenal and continue his duty at the arsenal therein. In after life in the service this man should be identified as much as possible with the particular specialty in which he was primarily trained.

The reserve officers whom the Ordnance Department must take in in case of war will by far constitute the greater part of the personnel during any major emergency. Assuming that the regular officers have been trained to their specialty, and in case of emergency are able to handle the more responsible positions, both in the field and in the manufacturing end, the question arises as to proper selection and training of reserve officers in time of peace for their duties in time of war.

There are really two classes of men who could be depended upon to make good reserve officers in time of war, the younger group, or college men of technical education, and the older group, or manufacturing men of the country. The R. O. T. C. as at present organized is counted upon to register the younger men while still in college and to keep in touch with them and hold them as long as possible after their graduation from college. The class of men desired for Ordnance reserve officers from the younger group are technical graduates from the best technical institutions. We want mechanical, electrical and chemical engineers. If we could get our quota from among these

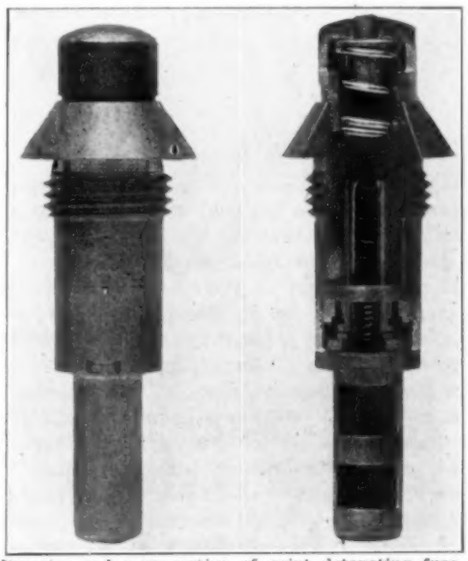
men we should be satisfied to let other graduates alone. These men in time of emergency would be able to take the principal official positions at manufacturing arsenals, and they could also fill the position of junior officers of ordnance in the field. They should be assembled once each year, preferably at Aberdeen Proving Ground, and given an intensive course in training, primarily touching on the things most interesting to them relative to ordnance. This period of training should be made practical and pleasant. It should tend to instill further interest and leave a man with a desire for further information. Care should be taken not to make it too technical and dry, so that interest may not lag. It is to be expected that as the R. O. T. C. group, recruited in any one year, advances in age, that due to various reasons it will become smaller and smaller. These cuts in the ranks should be filled by greater recruiting among the juniors, in order that a sufficient balance may always be available.

Concerning the older group of men who may be depended upon to serve, they should come from the younger group, advanced in years, and from the manufacturing interests of the country, particularly the technical manufacturing interests. These men are the ones who would supply the field positions of division Ordnance Officers and the positions back of the line requiring technical ability and administrative capacity. These men could be readily recruited from the manufacturing interests of the country. They should be technical graduates, should be men who have associated themselves with the Ordnance Department previous to the emergency, and men of age from thirty-five to forty-five, generally speaking. In time of peace their names should be carried in the organization files of the Ordnance Department in Washington. Their tentative assignments in case of emergency should also be kept.

In the lists of availables, as kept in Washington for this group, each potential reserve officer and actual reserve officer should have his particular assignment always made and on file. He should be invited at least once a year to visit the arsenal to which he is to be assigned in case of emergency, and given the opportunity to see what his probable duties would be. In this way the interest of these more experienced officers, who would probably have the rank of majors and lieutenant colonels, would be held.

With respect to both seniors and juniors in the Reserve Corps, it must be said that in a great sense the war service of the Ordnance Department depends upon them, so it is imperative in time of peace to see that suitable men for these senior and junior grades are kept listed, interested, and available.

As has been said before, ordnance activities are specialized activities. Activities requiring specialized officers also require certain specialized foremen and workmen. Because of good working conditions we find in every arsenal today men of efficiency and of long service. They have grown up in the design and manufacture of the various war components on which they work and with which they are connected. They are the men who have carried on and carried on well the policies of the department through the various changes, due to relief and detail of superiors in the commissioned grades. It is to these men that we must look to secure the necessary foremen to carry out any Government controlled activity in the production of munitions in time of war. They have proved themselves in time of peace and can be relied upon. Their training is as essential as is that of the officer. A certain number of these men are Ordnance engineers of tried value, others are superintendents in manufacturing arsenals, and still others are foremen. Since we are dependent on these men it should be kept constantly in mind by the Ordnance Office that salaries, working conditions, and general contentment of this class of employees should not be behind those of his coworker in other than Government institutions. It is only by assuring a proper living that we can expect to secure and retain men of this class. Their training is experience, their reward should be satisfactory advancement and an assurance of being taken care of in their advancing years. Up to the present time we have secured the proper men for all grades of work, and



Exterior and cross-section of point detonating fuze

are able, should a crisis arrive, to send out specialists in all lines of manufacture pertaining to munitions. We are fortunate in numbering among our civilian employees so many faithful and good men.

With respect to the soldiers of the Ordnance Department, it is believed that their duties should be confined strictly to duties in the field. If at arsenals at all, they should be only for station and police duties and should not be used for manufacturing purposes. In so far as ammunition companies are concerned, it is regretted that due to the small size of the Army at present proper training cannot be had. In the late war the ammunition companies and trains performed satisfactorily, and they probably would in another war. However, due to the run-down condition of our wartime trucks and equipment it is impossible to give the ammunition troops good training at present. For other than actual duty in the field we have at present at Raritan Arsenal a school for training soldiers in the duties of storage, supply, and maintenance of all kinds of ordnance matériel. This school is efficient and meets our peace-time needs. Of our technical sergeants it may be said that they are as a whole excellent men, well trained in their duties both for field and arsenal. Their training has been acquired usually from experience. We drew largely from this corps for our junior ordnance personnel during the last war and we should do so in another emergency.

With respect to the ammunition program as now laid down, it is hoped that it may be carried through. If we are to have satisfactory ammunition at the outbreak of a new war we must provide for certain replacements of the present stocks as they become old. Our present program provides for this. Let us hope that Congress will in the future appropriate the necessary funds for development and replacement, and thus assure that we may be on a sound footing so far as ammunition is concerned when the next emergency arises.

The Specific Heat and Thermal Diffusivities of Certain Explosives

PART II

By

A. M. PRENTISS

Outline of the Experimental Work

A study of the extensive and painstaking investigations of previous workers in the field of specific heat measurements makes it clear that the problem is a very exacting one if accuracy is to be secured. As pointed out by Richards and Jackson[1] in their very excellent work on the determination of the specific heats of certain of the elements, the problem "demands conditions which are almost self-contradictory, namely, great difference of temperature between different parts of the process and extraordinary thermal protection in one part of the apparatus. The conveyance of the cold substance to the protected calorimeter without either warming the cold substance or cooling the calorimeter may be said to be an impossibility; therefore, the solution of the problem must lie in discovering the magnitude of the unwished-for corrections and applying the results to the main experiment." In addition to these difficulties there were the ever-present precautions that have always to be observed in working with explosives.

A survey of the work of earlier investigators leads to the conclusion that the general methods and technique of Richards and Jackson[2] were, on the whole, best adapted to our problem. Some modifications were made in the apparatus to afford protection against possible accidental explosions, and it is believed that the use of thermo-couples instead of thermometers improved the general technique of the experimental work. In addition to affording a means of remote control, thermo-couples offered the further advantage of making all temperature measurements through a single system of apparatus which when properly calibrated insured against the accumulation of experimental errors.

In brief, the method adopted as most satisfactory consisted in cooling the substance contained in a metal capsule, by means of liquid air, transferring the capsule with the utmost rapidity from the cooler to the calorimeter, and then measuring the resulting changes of temperature. The technique involved thus resolves itself into three parts: First, the cooling; secondly, the transference; and thirdly, the calorimetric measurements. These operations will be discussed in the order named.

The Cooling Operation

The work of earlier experimenters showed that the best results were obtained by not immersing the substance directly in the cooling medium on account of the difficulties of accurately measuring the thermal effect of the adhering ice. Accordingly, the apparatus shown in Fig. 3 (see Part I of this article) was adopted. Various arrangements of thermo-element and cooling receptacle were tried before adopting the one selected and shown in Fig. 3. At first it was thought preferable to insert the small glass tube containing the thermo-element inside the test tube. This, however, necessitated the use of a test tube of much larger diameter in order to accommodate both thermo-element and capsule which considerably increased the time of cooling, the infiltration of heat, and the difficulty of rapid withdrawal of the capsule to such an extent as to more than offset the doubtful advantage of closer contact between the thermo-element measuring the temperature of the cooling medium and the capsule holding the explosive. It was also found by trial that the thermo-element in the cooling flask recorded the same temperature when inside as when outside the test tube, the only difference being in the time required to stabilize. The primary purpose of the thermo-element measuring the temperature of the cooling medium was not so much to record its actual temperature as to afford a means of ascertaining when complete thermal equilibrium between the cooling medium and the explosive charge is established. As the thermo-elements were all read by means of a common potentiometer by the null method, this all-important point could be determined, both in the cooling flask and the calorimeter, with a high degree of accuracy and all doubts completely eliminated. The uncertainty of complete thermal equilibrium has heretofore constituted one of the most troublesome features in calorimetry by the method of mixtures, and the elimination of this doubt constitutes one of the outstanding advantages in the use of thermo-elements with null potentiometer.

Various cooling agents were tried, including pure CO_2 snow, a solution of CO_2 snow in alcohol, and liquid air. The last was adopted for several reasons: it gave a much lower cooling temperature, resulting in a greater thermal range and more accurate determinations; it was also more convenient to handle and more consistent in the results obtained. The CO_2 snow proved troublesome to make, required considerable quantities to completely cool a sample charge, and had the very annoying feature of running out in the midst of an experiment. On the other hand, it was found that the flask full of liquid air would last from 48 to 72 hours, depending upon the number of charges cooled, and therefore specimen could be cooled over night. It was also found that no special means were required to surround the specimen with the cooling medium on top or to prevent the entrance of heat into the test tube during the cooling operation. A small wad of asbestos fiber was found to be a most suitable closure for the mouth of the test tube during the cooling operation. This was no doubt due to the fact that the atmosphere in the test tube at the temperature of liquid air is about three times as dense as the outside air at ordinary room temperature, and because of

1 The specific heat of the elements at low temperatures. *Zeitschrift fur Physikalische Chemie*, Vol. 70, 1910.
2 Loc. cit.

its density protects the cooling substance from convection currents.

Due to the density of the air in the cooling test tube, jacketed by the neck of the Dewar flask, it was found that by keeping the mouth of the flask below the level of the calorimeter, it could be brought to within a few inches of the calorimeter without affecting its thermal equilibrium. This greatly facilitated the manipulation and lessened the time required for transfer of the specimen.

Sufficient time for cooling the substance is a matter of primary importance. The failure of earlier experimenters to appreciate this point, it is believed, in a large measure accounts for the rather serious discrepancies in many of the results obtained. With our apparatus the method used to determine the length of time necessary for cooling was extremely simple and accurate. It consisted simply in reading on the potentiometer the successive voltages recorded from the two thermo-elements, one inserted in cooling medium and the other in the center of the mass of substance cooled. When both thermo-elements showed the same reading on the potentiometer, the thermal balance was complete. In the case of the substances under investigation, which are rather poor conductors, it was found more convenient to place this specimen in the cooling flask and let it remain over night. In this way measurements made just prior to transference always showed complete thermal balance.

Transference

Many schemes were tried for effecting the rapid transference of the substance from the cooler to the calorimeter, including apparatus to permit of distant operation for the protection of the operator. While no accidental explosions were to be expected from the sudden cooling of an explosive to the extremely low temperature of liquid air, or the just as rapid heating up to ordinary room temperature, and no such explosions did occur, at the same time, so far as could be ascertained, there is no record of explosives being subjected to such treatment. Therefore, it seemed only a matter of ordinary precaution to arrange things so that at least the first immersion and transference could be effected at a safe distance. Afterwards it was found that the substances under investigation could be safely handled in this way and the system of cords and pulleys used for distant manipulation was discarded in the interest of speed. It was ascertained by trial that the best method of transferring the capsule consisted in carefully raising it by the attached thermo-couple wire to the top of the cooling flask which, as stated, could be brought to within a few inches of the calorimeter, and then quickly withdrawing the capsule and plunging it in the calorimeter. As shown in Fig. 1* the cork cover of the calorimeter was permanently threaded on the wire so that closure of the calorimeter could be immediately effected after immersing the capsule. The thermo-couple wires were twisted into a pair and protected from the action of water in the calorimeter, and the very slight heating effect of the operator's fingers, by a double coat of rubber cement. It was found that raising the capsule in the cooling flask and holding the wires during transference did not produce any measurable reading upon the potentiometer during the brief interval of the operation. (See Fig. 5.)

The envelope of cold air surrounding the capsule produced during tranference automatically compensated to a greater or less degree for the warming effect of the room atmosphere upon the capsule during its passage through the air. As the warming effect was directly dependent upon the time required to transfer the capsule from the cooler to the calorimeter while the cooling effect was much more independent of this factor, it was found that by properly adjusting the speed of transference, these two effects could be made to balance and cancel each other. The optimum time of transference was thus found to be about one-half second, an easily attainable speed for this operation.

In order to determine the net result of the heating and cooling effects, the method of Richards and Jackson was followed. A blank experiment was run in which the empty aluminum capsule was cooled and plunged, the usual calorimetric measurements taken, and its specific heat determined. After applying a small correction for the cooling effect of the cold air contained in the capsule, the difference between the known specific heat of aluminum for the given range of temperature and that determined for the blank experiment was obviously due to the resultant of the cooling effect of surrounding cold air and the heating effect of the room atmosphere on the capsule during transference. If the specific heat of the aluminum capsule was higher than the established value for aluminum, it indicated that the cooling effect of the air surrounding the capsule predominated over the warming effect of the room atmosphere during transference, whereas, if the specific heat determination was too low, it showed that the reverse condition obtained. By properly adjusting the time of transference, the net correction could be made a negligible quantity.

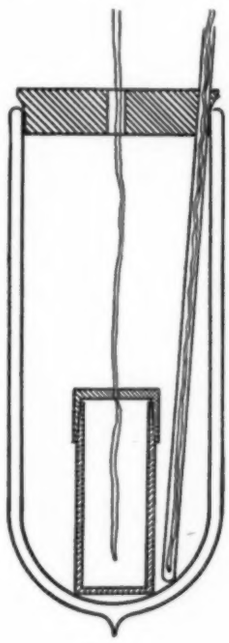


Fig. 1

Thus the empty aluminum capsule, weighing 49.365 grams and containing 15.60 c.c. of air, was cooled to a constant temperature of —190.245° while the temperature of the calorimeter at the instant of transference was ascertained to be +26.919°. After transference, the temperature of the calorimeter dropped to +22.490° and remained constant except for a very slight radiation loss which was determined by Rowland's method and found to be so exceedingly small as to be altogether negligible. Under these circumstances, the specific heat of the capsule was calculated as follows:

$$\frac{(400.00 + 14.74) \times (26.919 - 22.490) - 1.030}{(190.245 + 22.490) \times 49.365} = .17468$$

*For convenience of the reader Fig. 1, which appeared with Part 1 of this article in the September-October issue of ARMY ORDNANCE, is repeated here.—Ed.

where 400,000 is the mass of water in the calorimeter, 14.74 is the water equivalent of the calorimeter; and 1.030 calories is the correction due to the air in the capsule.

The specific heat of aluminum over the same range of temperature was established by Richards and Jackson[1] at .1748. The above determination was within .07 of 1 per cent of this value and was thus well within the experimental limit of our apparatus, showing that the net correction for warming and cooling effects of transference had been reduced to a negligible quantity.

In order to check this point in another way the same capsule was filled with 9.688 grams of powdered aluminum, taken from an hermetically sealed bottle, quickly packed into the capsule and sealed, and the above experiment repeated under identical conditions. The capsule was cooled to a constant temperature[2] of —191.250° while the calorimeter temperature at the instant of immersion was +27.735°. After immersion the calorimeter temperature dropped to +22.418° and remained constant. The specific heat of the capsule and contents (all aluminum) calculated as above was, therefore, as follows:

$$\frac{414.74 \times 5.317 - .796}{213.668 \times 59.053} = .17470$$

The difference between thermal effects of the capsule in the two experiments was obviously due solely to the difference of the 9.688 grams of aluminum filled in the capsule. The result calculated from this difference (see Fig. 4) eliminates any error due to the heating and cooling effects during transference.

The true specific heat of aluminum is thus calculated as follows:

$$\frac{0.17470 \times 59.053 - 0.17468 \times 49.365}{9.688} = .17480$$

which coincides exactly with the average value established by Richards and Jackson.[3]

As the apparent specific heat of the empty capsule was less than that of the capsule filled with aluminum, it is evident that the effect of the descending cold air from the cooling apparatus was less than the effect of the warming which the capsule sustained on passing through the air. Thus the preponderance of the warming effect was enough to make the specific heat of the filled capsule 0.05 per cent too low and that of the empty capsule 0.07 per cent too low.

The fall of calorimeter temperature was 5.317° in the former case and 4.429° in the latter case, after correcting for the effect of the .871° difference in cold temperature of the capsule in the two cases. The net effect on the calorimeter of the warming during transference is established as 0.005°. This figure was checked by four similar determinations and found correct as an average value. Hence it is clear, under our experimental conditions, that the warming effect of the air upon the cold capsule during transference completely compensated for the effect of the cold air from the cooling apparatus and exerted but an exceedingly small net warming effect on the calorimeter.

Measurement of the Change of Temperature

Having discussed the method of transference of the cold body to the calorimeter, we may now pass to a consideration of the third step in the process, namely, the measurement of the change of temperature produced in a known heat capacity by the warming of the cool substance to the room temperature.

The calorimeter used in all taking measurements has been described. It may be noted that it has been reduced to its simplest form and all foreign bodies and auxiliaries have been eliminated. It was found that vigorous stirring with a mechanical stirrer produced a rise in temperature in the water which varied somewhat, due to difficulty of maintaining a uniform speed of the stirrer at all times. Also the glass rod of the stirrer permitted some loss of heat by conduction, so that, on the whole, more uniform and consistent results were obtained by utilizing the glass tube of the thermo-element and the capsule itself as stirrers. Due to the relative size and shape of the calorimeter, by means of the thermo-couple attached wires, produced an excellent agitation of the water by a sort of loose piston action. This, together with gentle stirring with the thermo-couple glass tube, secured ample and satisfactory agitation, greatly simplified the apparatus, and gave more uniform and certain results.

In order to reduce the radiation correction to a minimum the amount and initial temperature of the water used in the calorimeter was adjusted so as to make the final temperature in the calorimeter closely approximate the room temperature.

The best method of securing this control was found to consist in using a constant quantity of water and by trial runs to determine the approximate temperature to which this water must be raised in order to make the convergence temperature equal that of the room. Accordingly, for every determination, a little over four-hundred grams of distilled water at room temperature was weighed out, heated to the predetermined temperature, usually about 5° above room temperature, and its weight carefully brought down to 400.000 grams by removing the excess weight of water with an eye dropper. When the requisite temperature and weight were obtained the water was transferred to the calorimeter and its temperature observed at minute intervals until stable. As the drop in temperature of the water in the calorimeter was usually not over 5° during a determination and its final temperature closely approximated that of the surroundings, the radiation correction was so small that, in nearly every case, it was a negligible quantity as far as our final results were concerned. The magnitude of the radiation correction in any case was determined by Rowland's method, which readily lends itself to the character of our time-temperature readings.

The manipulation of the calorimeter consists simply of stirring the warm water introduced as described above with the glass tube containing the thermo-couple until a sensibly constant temperature was recorded. Stirring with the thermo-element afforded the double advantage of eliminating an extra stirring rod and at the same time obtaining temperature measurements in all parts of the calorimeter. When the temperature in the calorimeter was steady the cover was removed and the cold capsule dropped in by its thermo-couple wire and the cover immediately replaced. The water was kept in constant circulation by raising and lowering the capsule and stirring with the calorimeter thermo-element, and temperature observations at half-minute intervals were then read until an approximately constant temperature was again recorded and thereafter at three-minute intervals until stabilization was complete. This method of calorimetry was found to eliminate the usually troublesome uncertainty due to the difficulty of quickly mixing the cooled water with the warm water during the period of rapid change.

After each determination the water was emptied into a beaker, carefully heated again to its predetermined temperature, its weight brought up to 400.000 grams by adding a few drops with an eye dropper, and returned to the calorimeter which was completely dried in the interim.

1 Loc. cit.
2 This lower temperature was attained because the cooling flask had just been refilled with liquid air.
3 Loc. cit.

A Typical Example of a Specific Heat Determination

Having discussed in a general way the various separate features of the work, we may now consider a typical determination (that of TNT.) in detail in order that all the calculations and observations may be duly understood and comprehended. Following this, the remainder of the observations are condensed in the form of a table giving all essential data but not the great bulk of separate observations.

The aluminum capsule shown in Fig. 1 was loaded with approximately 12 grams of the explosive which was consolidated by pressure to a density of 1.00. The density of loading was determined as follows: The capsule was carefully weighed before and after loading with explosive, giving the net weight of the charge. The space occupied by the charge was then determined by gauging the empty space above the level of the explosive and calculating its volume, which was deducted from the capacity of the capsule.

In loading the capsule great care was taken to see that the thermo-couple junction was equispaced from the folds of the aluminum foil and imbedded in the center of the mass of explosive, after which all traces of explosive were carefully removed from the outside of the capsule, a small trace of stop cock grease smeared around the conical seat of the cover, and the cover firmly pressed on. As mentioned above, it was found that if the cover were seated with sufficient pressure no additional means were required to hold it to its seat with a water-tight fit.

The capsule after loading was put in the cooling flask and usually left over night so that, in nearly every case, the time of cooling was from 12 to 24 hours. The capsule having thus attained a stable low temperature, the calorimeter was then filled with exactly 400.000 grams of water previously heated to about 5° above room temperature and the rate of temperature change of the calorimeter was determined by reading the calorimeter thermo-couple every minute until this rate was well established. The temperature of the capsule in the cooler was also read at minute intervals alternately with the calorimeter readings to establish any rate of temperature change that might be taking place in the capsule. Immediately after taking the last calorimeter reading, the capsule was transferred with all possible speed to the calorimeter, the cover of the calorimeter being quickly raised during this almost instantaneous transference. During the experiment the room temperature immediately surrounding the calorimeter was read at two-minute intervals on the mercury thermometer. After reducing these readings to standard they were entered opposite calorimeter readings.

Three observers were employed during each determination. One operated the potentiometer and read all thermo-electric observations. He was responsible that the zero setting on the galvanometer scale was correct at the beginning of each series of observations. In order to insure this before each run the potentiometer was balanced against the standard cell and the short circuit reading taken after throwing in the eliminating switch. In this way any drift due to temperature changes in the dry cells or to parasitic currents was duly observed and corrected by shifting the normal on the galvanometer scale. A second observer read the room thermometer, transferred the capsule, and constantly stirred the water in the calorimeter throughout the experiment. The third observer read the time and coordinated the time-temperature readings by calling "Read" to the potentiometer operator exactly on the minute intervals. The third observer also recorded all readings as well as weights and various other experimental data.

For the first two or three minutes after immersing the capsule in the calorimeter the temperature of the calorimeter fell with such a speed that it could not be observed on the potentiometer with any degree of accuracy. But the elapsed time required to get the first reading was duly observed so that the time-temperature readings could be plotted as a continuous curve. For ten minutes the temperature of the calorimeter fell steadily but with decreasing speed. After twenty minutes the temperature again became sensibly constant except for the very slight cooling rate due to difference of about 1.5° above room temperature. See table of readings on page 188.

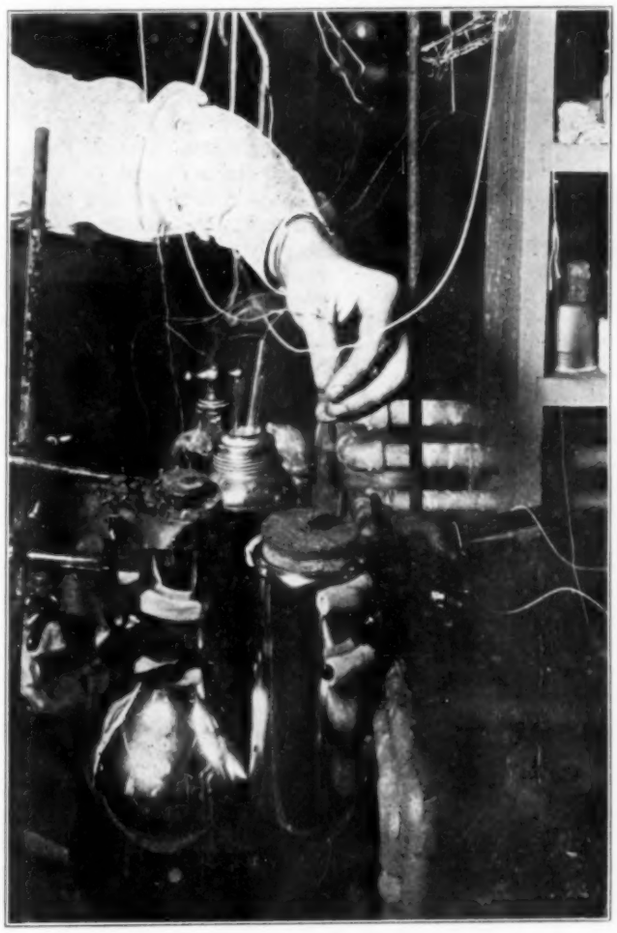


Fig. 5

At the beginning of the experiment the calorimeter was cooling at the rate of 0.0017° per minute while the temperature of the explosive in the capsule was sensibly constant. Computing from its rate of temperature change the temperature of the calorimeter at the instant of immersion was +23.252° while the capsule was —184.816°. The temperature of the calorimeter and capsule coincided 22 minutes after immersion, showing equalization of temperature was complete at that instant. From the rate of cooling of the calorimeter its temperature the instant after immersion was found to be 23.152° had there been no exchange of heat with the surroundings. The corrected fall of temperature of the calorimeter was 5.613°, of which .005° has been shown to be due to the warming effect of the atmosphere during transference. The cooling effect due to the air in the capsule was found to be .53 calories.

The water equivalent computed as indicated above was 414.74 calories. The empty capsule had an average heat capacity of 8.624 grams, therefore, the quantity of heat absorbed by it was 1791.73 calories, leaving 535.45 calories as the heat taken in by the TNT. As this heat raised 12.008 grams of TNT. from —184.816° to +23.152°, the average specific heat over this range is found to be 0.2144.

Three other similar determinations were likewise made and entered in the table below. This table contains all the specific heat determinations not rejected for palpable errors. The method of tabulation is that adopted by the *Zeitschrift für Anorganische Chemie* in publishing international atomic weights. In the column next to the last there is recorded the average heat capacity of the containing vessel which was the same throughout all the determinations. This quantity must always be multiplied by the total rise in temperature ($\triangle t'$) given in the column next preceding to find the amount of heat subtracted from the calorimeter by the containing vessel.

The general equation for calculating all the above results is:

$$\text{Specific heat} = \frac{H \triangle t - C \triangle t'}{W t}$$

in which the symbols are as defined at the top of the respective columns in the table.

The following table gives, in the last column, the results for the specific heats of the substances tested, expressed in 20° calories divided by international centigrade degrees:

Table of Readings

Time	Calorimeter Reading (Microvolts)	Capsule Reading (Microvolts)	Room Temperature in °C
8.50	------	5290	-----
8.51	1147.7	------	24.30
8.52	------	5290	-----
8.53	1146.8	------	24.30
8.54	------	5290	-----
8.55	1146.0	------	24.30
8.56	------	5290	-----
8.57	1145.2	------	24.30
8.58	------	5290	-----
8.59	1144.3	------	24.30
9.00	------	5290	-----
9.01	1143.5	------	-----
9.02	Immersion	------	24.30
9.03	------	------	-----
9.04	916.3	------	-----
9.05	916.5	------	-----
9.06	916.7	------	24.30
9.07	916.9	------	-----
9.10	917.0	------	-----
9.11	------	720.0	-----
9.12	917.2	------	-----
9.13	------	837.0	24.30
9.14	917.4	------	-----
9.15	------	880.0	-----
9.16	917.6	------	-----
9.17	------	901.5	-----
9.18	917.8	------	-----
9.19	------	913.0	24.30
9.20	918.0	------	-----
9.21	------	915.0	-----
9.22	918.2	------	-----
9.23	------	916.7	-----
9.24	918.3	------	-----
9.25	------	918.2	24.30
9.26	918.3	------	-----
9.27	------	918.3	-----

(Part III of this article will appear in the January-February, 1924, number of ARMY ORDNANCE.)

Table of Specific Heat Determinations

No. of Exp.	Symbol of substance	Weight of substance	Time cooled (in hours)	Water equivalent of calorimeter =H.	Final t°	Corrected fall of t° of water=$\triangle t$	Rise of t° of substance=$\triangle t_1$	Heat capacity of container=C	Specific heat of substance
1	TNT.	12.008	24	414.74	23.152	5.613	207.968	8.264	.2144
2	TNT.	12.008	24.5	414.74	23.241	5.624	209,000	8.264	.2110
3	TNT.	12.008	22.5	414.74	23.145	5.620	208.520	8.264	.2125
4	TNT.	12.008	23.5	414.74	23.075	5.615	206.954	8.264	.2186
								Average	.2141
5	TNT.	11.995	24.5	414.74	22.615	5.566	210.160	8.264	.2267
6	TNT.	11.995	24	414.74	22.895	5.474	207.182	8.264	.2244
7	TNT.	11.995	24	414.74	23.062	5.353	206.824	8.264	.2235
8	TNT.	11.995	23.5	414.74	23.140	5.252	208.543	8.264	.2253
								Average	.2244
9	Tetryl	12.003	24	414.74	22.695	5.638	209.520	8.264	.2414
10	Tetryl	12.003	24	414.74	23.172	5.614	208.950	8.264	.2398
11	Tetryl	12.003	24.5	414.74	22.970	5.649	206.634	8.264	.2406
12	Tetryl	12.003	24	414.74	23.142	5.540	206.100	8.264	.2402
								Average	.2405
13	TNT.	12.170	24	414.74	25.677	4.831	174.397	8.264	.2534
14	TNT.	11.585	24	414.74	25.258	0.786	25.077	8.264	.3776

A New Detonating Explosive

A brochure recently published by the Bureau of Mines contains some very interesting data on cyanuric triazide, a comparatively new detonating compound that has been erroneously reported in the press as a substitute and possible alternative for military use of mercury fulminate.

The pamphlet recites the various patent claims; it gives methods of preparation; properties and detonation strengths, and a report on the detonation efficiency.

The conclusions of the authors, Messrs. C. A. Taylor and William H. Rinkenbach, are interesting. They state: "Cyanuric triazide is a very efficient detonating agent, but is too sensitive to handle safely in large quantities. It is especially sensitive in the form of large crystals such as may be formed from fusion or re-crystallization. It is non-poisonous, but the materials used in its manufacture are irritating and poisonous."

Professional Notes

Artillery Division: The French Long-Range Gun

Recent press dispatches from Paris state that the French 60-mile gun has recently been sent from the Ruelle Arsenal to the Gavres Proving Ground for test. This is France's largest and most powerful gun. It is understood that the weapon has a range of 97 kilometers (sixty and a half miles). The projectile is said to weigh about 1,100 pounds.

This gun was originally constructed during the World War in retaliation to the German long-range run which shelled Paris and which is described in full in Colonel Miller's article in this issue of ARMY ORDNANCE. The French gun was not put into use during the war, however, because it was found that the railroad viaducts out of the arsenal at Ruelle were not strong enough to permit its transport. The road and bridges have been reinforced since the war and the great gun is now under test.

Flexible Track Link and Shoe for 75-mm. Gun Motor Carriage (1924E)

In the November-December (1922) and March-April (1923) issues of ARMY ORDNANCE, descriptions of the "Snake" type of flexible type of track were printed. This track, substantially as outlined on page 174, November-December, 1922, ARMY ORDNANCE, is to be applied to the Army Tractor, Model 1922E, and serve as a basis for the track to be later used on a new 15-ton tank. This type of track consists of a series of links joined together by means of ball joints which allow the adjacent links to be at any angle to each other within certain limits and allow them to rotate to any angle within the limits of the shoe striking and rubbing along the lower ledge of the truck frame side plates. This track adapts itself well to heavy vehicles.

The flexible track to be used on the 75-mm. Gun Motor Carriage, which is a vehicle of about five tons weight, while of the flexible type, differs considerably from the "snake" track applied to the heavier vehicles. This track, construction of which is shown on Fig. 1, consists essentially of a series of links joined in such a manner as to allow universal action but no rotation between adjacent links; tubes which act as rolling surfaces for the truck wheels, serve as a lubricant retainer around the links, and which are welded to the track shoes; pins held in the link and protruding through clearance holes provided in the tubes which serve as driving pins and also as limit stops to the relative rotation between track shoes and links.

One of the features of this track link and shoe is that the two functions of a track, namely, carrying and pulling —are taken care of separately, the links and pins being the pulling parts, while the tubes and shoes serve as carrying parts. The tubes, which are free to rotate on machined cylindrical surfaces on the links, serve as pivots for the track shoe in accommodating themselves to transverse irregularities of the ground. They also act as oil retainers around the links, carrying a considerable amount of oil or light grease in each track link. The oil retaining pockets are open to each other, making a continuous oil retainer. Instead of filling each track link separately, only three or four links in each track need to be opened and filled to lubricate the entire track. The link connection, while of a peculiar construction, provides greatest strength and bearing area possible in a given diameter of track tube.

Rubber blocks are provided with this shoe, and can be used or not. Rubber blocks should have a considerable life, as with this type of flexible track and suspension there is no necessity for liding the tracks on the ground in making a turn as in the previous tracks on which rubber blocks have been tried.

Development of Fabric Track

For the last three or four years a considerable amount of study and effort has been put upon the development of a fabric type of track. Of the different types the one on which the most effort has been expended is the one known as the "Chase" type which was designed to run on pneumatic tires. The track or belt consisted of two pieces of belting attached to each other by means of numerous steel pieces bent to fit the tire, and extending across the tire and beyond it sufficiently to permit the attaching of the rubberized fabric belt. The track therefore consisted of two belts running parallel and lying at either side of the pneumatic wheels. Attached to these belts and spaced at about every six inches are the steel cross pieces.

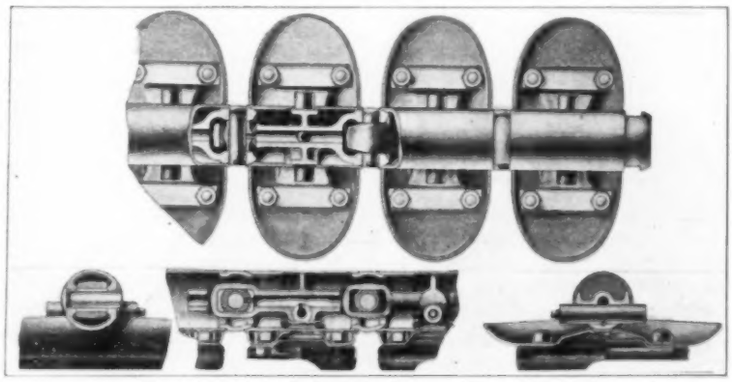


Fig. 1. Track Link and Shoe for 75-mm. Motor Gun Carriage, Model 1924E

After a close study and analysis of this type of development it is considered improbable that any successful track can be made from this design. This conclusion is based on the following reaons:

(1) There is no positive method for driving the track belt, and therefore driving wheels slip within the belt. To attempt to put lugs on the driving wheel would not be practical as pitch of cross-members on the belt cannot be maintained.

(2) The method of mounting the wheels on the vehicle is wrong. Especially is this true on the Dodge Light Re-

pair Truck as soon as weight is taken on the idler, and therefore off of the driver, traction is lost.

(3) To cut holes in a belt to attach metal parts is wrong as by test it is found that a reduction of the section by but 20 per cent by means of holes reduces the strength 50 per cent. Also, metal strips cause abrasion of the belt.

(4) Standard belts cannot be found suitable for this purpose.

The above is all based on past methods of drive and structure. New studies are now in process and are based upon the following ideas:

(1) The discontinuance of all attempts at combinations of metal and fabric belts.

(2) Reduction of the stress upon the belt by driving through all wheels except steering wheels.

(3) To make an entirely new and special type of belt of rubberized fabric and of sufficient strength to withstand the service conditions.

The first idea consists in driving all the wheels over which the track or belt runs. This means that the present system of suspension must be changed. This is now being worked out on the Dodge Light Repair Truck for test.

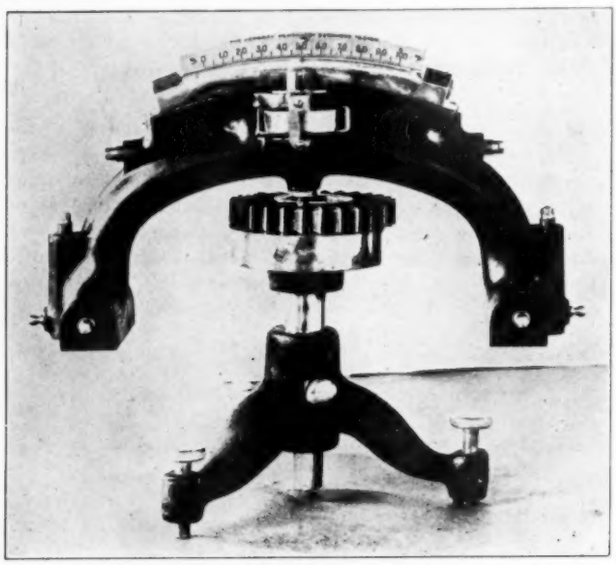


Fig. 2. Herbert Pendulum Hardness Tester

The second idea consists in making a track of the same type as the Citroen and making demountable rims to go on the regular wheels in order that the vehicle may be convertible, either as a tracklayer type or for pneumatic tires. It may be found necessary in this type to drive all wheels.

Parts are being ordered for these two lines of development at the present time. It was planned at first to attempt to make a special built-up belt to run on pneumatic tires, but after taking the subject up with the rubber companies and observing the operation of the "Chase" track on a Dodge vehicle, it was decided that the development of such a track was not practical on account of the fact that it would be impossible to manufacture a track or belt which would stay on the wheels satisfactorily.

A spring thrust rod, to be placed between the two wheels, is also being made for test. This feature is made for the purpose of maintaining a constant tension on the belt and relieve the load on the belt when going over rough ground.

The Herbert Pendulum Hardness Tester

An extremely simple instrument for hardness testing has made its appearance in the Herbert Pendulum Hardness Tester. The machine is portable and quick in action, a test occupying only a few seconds. Heavy loads are not used, and the test may be applied to thin and fragile articles without risk of breakage or defacement of finished surfaces.

The instrument consists of a ball, one millimetre in diameter, which is held in a chuck in the center of the instrument, and six screwed weights are provided whereby the position of the center of gravity of the whole instrument may be adjusted to coincide with the center of the millimeter ball. The instrument is made in two weights, 2 kilograms and 4 kilograms respectively, their dimensions being identical. The ball is of ruby or of steel.

Immediately above the ball is a graduated weight mounted on a screw. By raising or lowering this weight the center of gravity of the instrument can be brought to a predetermined distance above or below the center of the ball. The graduations on the weight show displacements of the center of gravity in hundredths of a millimeter. A curved tube and bubble and a scale, graduated from 0 to 100, are fixed at the top of the instrument.

The center of gravity being at the center of the ball, the instrument is in neutral equilibrium when supported by the ball on a hard level surface. It tends to remain in any position in which it may be placed, whether upright or tilted at an angle.

If the center of gravity is above the center of the ball the equilibrium may be unstable, in which case the instrument tends to "lie down" in one direction or another.

If the center of gravity is below the center of the ball the equilibrium is stable. The instrument constitutes a pendulum oscillating about its central position, the time of oscillation being greater as the length of the pendulum (the distance between the center of gravity and the center of the ball) is less.

For standard tests the length of the pendulum is one-tenth of a millimeter (.0039 inch), and the time of a single swing on a very hard surface is 10 seconds.

This tester provides two independent tests of hardness, which depend on different principles and measure different kinds of hardness. Each test has a scale of hardness numbers from 0 to 100, but the hardness numbers of a given substance are not the same on the two scales. Generally, substances are placed by the two tests in the same order of hardness, but in some cases (*e.g.*, two pieces of the same steel which have had different heat treatments, or two substances having different characteristics such as cast iron and steel), the specimen which is shown harder by one test may be softer according to the other.

The instrument is of British manufacture and as yet little has been heard of its effectiveness from users in this country.

Rock Island Arsenal: Manufacturing Limits in Gun Carriages

The establishment of correct manufacturing limits on Ordnance drawings is a very important step in their completion. Undoubtedly the Ordnance Department is anxious to avoid in the future such situations as developed in 1917-18 when certain manufacturers began to realize the very close work required by the Government, and is willing to set manufacturing tolerances within reach of the commercial shops that must be depended on for future manufacture in quantity.

The designer of gun carriages does not get much direct assistance from trade or technical magazines as to manufacturing limits in some of the rather unusual features of his work, nor can he be altogether guided by the practice of very well equipped arsenals able to produce well-nigh

perfect pieces. He confidently expects the inspector to insist on an entire lack of lost motion in the elevating and traversing mechanism of gun carriages and at the same time knows that every machine shop will cry for latitude on dimensions. Perhaps if the mechanical engineers of the country would express their sentiments in a few concrete instances they would materially help to fix the policies of the Department in ways mutually acceptable. Consider the elevating mechanism of the 4.7-inch gun carriage. M1921E. (See Fig. 3.)

In this machine the gun slides in a cradle which is provided with bolted-on trunnions. These trunnions rest in roller bearings at the upper ends of a yoke called the "top carriage." Dovetailed and keyed to the underside of the cradle and concentric (?) with the trunnions is a segment of worm gear meshing with a worm lying in bearings in the lower part of the top carriage. Revolution of the worm moves the worm segment or "elevating arc" and raises or depresses the muzzle of the gun resting on the cradle. The weight of the gun and recoil mechanism in the cradle takes up the clearances in various bearings (except in the bearings of the worm) in a direction generally tending to pull the elevating arc away from the worm. It also produces a certain amount of deflection or "sag" in the trunnions and cast-steel top carriage. The deflection direction is somewhat affected by the force exerted by the equilibrators in different positions of the gun. The difficulty of machining the seat for the worm in exactly the right center distance from the seats of the roller bearing in the top carriage yoke makes it necessary to establish considerable manufacturing tolerances on this dimension unless it be assumed that expensive machining jigs are to be provided. It is clear that if the elevating arc be not exactly concentric with the center of the revolution at the trunnions, or if it be slightly off the plane of the worm sidewise, binding may result. Add to this the desire of the Ordnance Department that all parts of gun carriages that may need replacement be strictly interchangeable and the result is a difficult machine-shop problem.

Instead of holding the manufacture of all components to very close tolerance an alternate method consists in providing reasonably close tolerance upon (*a*) the distance from the center of trunnions down to the plane of the under side of the cradle (the trunnions are finished in place after bolting on cradle), (*b*) the components of roller bearings, (*c*) distance trunnion center to worm seat in top carriage, (*d*) diameter of worm (including pitch diameter), etc., then to assemble the entire vehicle including the gun, except the worm, and to put in place a fine cutting hob representing the worm (in which the teeth have been previously formed nearly to size) in the worm seat and finish the elevating arc. This method will, of course, destroy the interchangeability feature of the elevating arc which, by the way, being a heavy forging not overly exposed to damage, will be rarely replaced. This method will moreover take care of any inaccuracy whatever in the series of bearings or setting of the elevating arc and will reduce the lost motion of the elevating system to a minimum. It is, however, open to the objections usually connected with work which has to be fitted in assembling. The question to be settled by the engineers or by the technical staff is whether the requirement of *no lost motion* is so important as to require the trouble. Some artillerymen argue that it is not important at all, since if the carriage has the proper breech preponderance and the gun is laid on the target as it should be by depressing the muzzle, all lost motion in the elevating mechanism is thereby taken up in the direction to resist the stress resulting from firing and therefore there is no lost motion to accentuate the stresses in the carriage or affect the accuracy of the piece. The counter recoil, however, would probably produce undesirable effects where the lost motion is of any great amount. It is quite possible that the opinion of mechanical engineers generally would be welcomed by the Ordnance Department as to what practical manufacturing limits could be set in commercial shops upon the distances (*a*) trunnion to underside of cradle, (*b*) trunnion bearing to worm seat in top carriage, and (*c*) pitch radii of worm and arc. It is felt that at a manufacturing arsenal such limits might be set too close. Or, (*d*) would it prove possible to design a hob representing a worm of 4-in. pitch diameter, 3½ diametrical pitch, which would finish the arc in place as suggested.

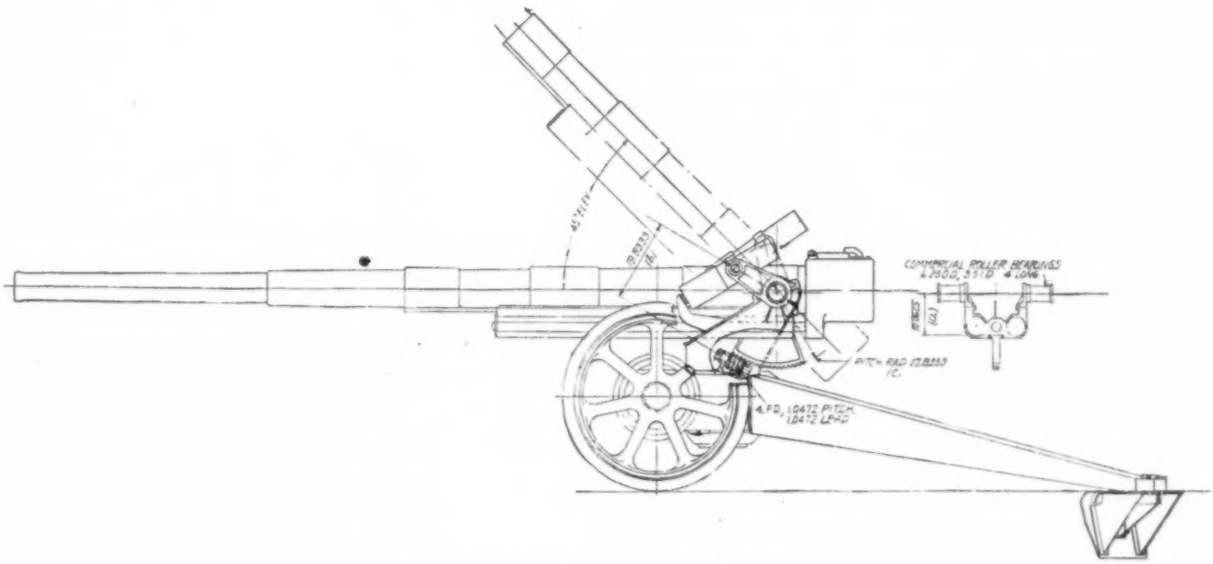


Fig. 3. 4.7-inch Gun Carriage, Model 1921E

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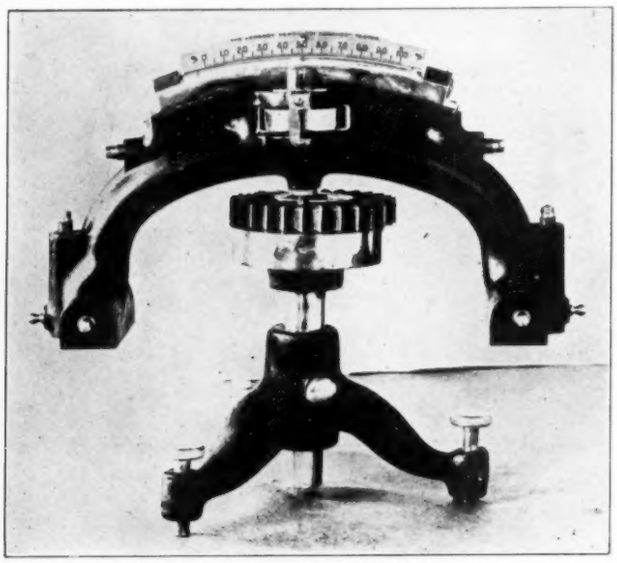

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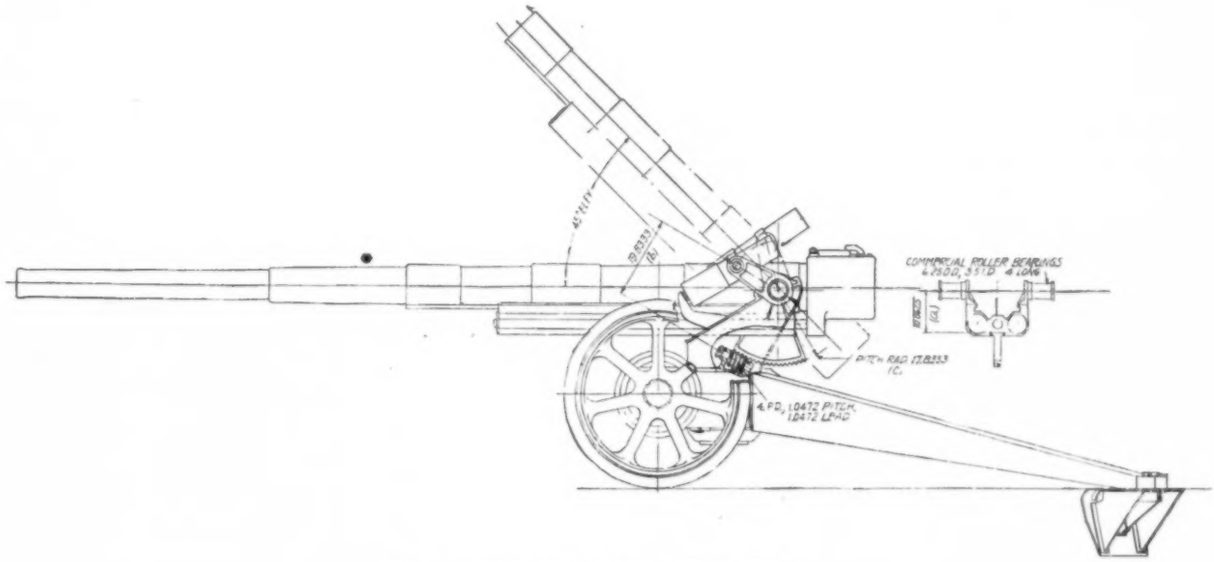

Fig. 3. 4.7-inch Gun Carriage, Model 1921E

Benzol and Toluol for the Next War

(*Continued from Page 160*)

shown diagrammatically in Fig. 2. This indicates continuous operation; the gel leaves the actifier (A) and is forwarded by the blower (B) to the cyclone (C); from the cyclone the gel enters the cooler (D) and passes from there to the screw conveyor (1), where it meets the partially stripped gas coming from the cyclone (E). This gas carries the gel from conveyor (1) up through the tubular absorber (F), where contact between gas and gel is effected and where the benzols are absorbed, after which both gas and gel enter the cyclone marked (G) where the gel is separated from the gas and it passes down to conveyor (2), again meeting gas from cyclone (H) and being carried up through the tubular absorber (J); the gel is again separated from the gas in cyclone (E) and meets the fresh or rich gas in conveyor (3), passing up through absorber (K), and the final separation is made in cyclone (H), from whence the gel passes into a "Wedge"-type furnace actifier (A); it is heated here by the hot gases coming from the furnace (L), the oil vapors thus produced leaving the actifier and being condensed in the condenser (M), and the benzols thus recovered are sent to the storage tank (N). The stripped gas from the last cyclone (G) enters the bag filter (O), where any entrained gel is recovered and sent on with the current of gel coming from the cooler (D). The fractionation and purification of these recovered benzols is, of course, conducted similarly as explained before.

This plant, from its nature, would certainly require a greater capital outlay than would the intermittent 3-box plant just described, but it is continuous in operation. The life of such a continuous apparatus is, however, very problematical, since the gel is quartz-like in hardness and but a few seconds are required to forward a grain of gel from the actifier, carry it through the system, and return it to its point of origin; it would therefore appear that the excessive abrasion produced by this swift moving, finely divided quartz-like material would soon wear out almost any material of which the apparatus might be constructed, resulting in costly replacements in a very short time.

General

The heating value of the gas thus treated will, of course, be somewhat reduced, and the net heating value of the treated gas may be estimated by the Schaeffer equation, which closely approximates the actual condition; or

$$\text{B.T.U.} = \frac{a - 121827\,b}{1 - 35\,b},$$

in which, a = the heating value in B.T.U. of the gas before treatment.

b = the fraction of a gallon of light oil removed from a cubic foot of gas.

35 = the number of cubic feet of vapor produced by a gallon of light oil.

The constant, 121,827, is the product of the heating value per pound of light oil (17,567 B.T.U.) by 7.3 (weight of a gallon of these light oils) by 0.95 (a factor to correct for the amount of wash oils in the light oil, which is assumed in the equation to be 5 per cent).

If we assume a recovery of 3 gallons of light oil per 2,000 pounds of coal carbonized, resulting in the production of 10,000 cubic feet of gas, the light oil per cubic foot of gas will be $3 \div 10{,}000 = 0.0003$ gallon, and if the untreated gas has a thermal value of 550 B.T.U. per cubic foot, we will have for the treated gas

$$\frac{550 - (121827 \times 0.0003)}{1 - (35 \times 0.0003)} = 508 \text{ B.T.U.}$$

or there will be a reduction of $555 - 508 = 42$ B.T.U. per cubic foot of gas, amounting to 7.6 per cent of the original thermal value.

The loss in candle power may be estimated as follows: For every 1,000 cubic feet of gas treated we remove 0.3 gallon of light oil, and as every one-tenth of a gallon is equivalent to 2.86 candles, the loss will be $2.86 \times 3 = 8.58$ candles, or the loss will be 39 per cent of the original candle power.

If the benzol is not to be recovered, or if the operation is to embrace only the ultimate recovery of toluol, the crude benzol fraction containing olefines may be vaporized and returned to the gas, in which case both the thermal value and the candle power of the treated gas will be somewhat increased.

A sudden national emergency which would call on the city gas plants to remove the toluol, or both benzol and toluol, from the gas, would necessarily cause quite some difficulty, since practically all gas plants are operated under either thermal or candle power restrictions, or sometimes under both. This condition will cause or create quite a difference in the expense account of the producer due to the shrinkage in the volume of the gas by the extraction of the light oil vapors; to the extra cost of manufacturing gas in close proximity to a hazardous undertaking; and to the necessary increase in overhead charges in the conduct of this additional business.

Again, the ability of the gas company to completely cover its business of supplying gas to the consumer must also be considered. With a reduction in heating value, it may be necessary to supply an increased volume of gas to the consumer to make up this deficiency, or if the consumer must pay for more gas to secure the same heating effect, it will be necessary for the gas company to increase its supply and this may not always be done readily.

The effect of light oil removal may also have a very uncomfortable effect on the consumer, if the additional volume of gas is not available. It may be truly stated that, next to water, artificial gas is probably the most essential article entering into the domestic life of the city dweller. During recent years many houses have been erected with no provision for any fuel for heating and cooking other than gas, and in many cases no other fuel could possibly be used because the houses have not been constructed with flues for taking care of the combustion products from solid fuels. In many of the large cities it is estimated that 90 per cent of the houses depend on gas for cooking purposes, while in some cities about 80 per cent of the homes depend on gas for lighting.

To this general consumption must now be added an increased volume of gas due to the removal of some of the heating and lighting values which have been put to other and more important uses, consequently the new demand for gas thus placed on the producing companies may possibly be more than they can supply. These conditions all require very careful study, as money is not always available for making extensive additions to the existing plants for the supply of this additional gas, and in demanding benzol and toluol from the gas companies these conditions will require compromises of some character.

Reserve Corps Notes

Brigadier General Samuel McRoberts

The promotion of Colonel Samuel McRoberts, Ordnance Officers' Reserve Corps, to the rank of Brigadier General was announced recently by the Secretary of War.

General McRoberts served with distinction as Chief of the Procurement Division, Office of the Chief of Ordnance, during the World War and with the American Expeditionary Forces in France.

He was commissioned a Major in the Ordnance Reserve Corps during November, 1917, and in December of that year he became chief of the Procurement Division, and, as such, he was responsible for the purchase of all ordnance material. In August, 1918, he was transferred to France and was thereafter actively engaged either in providing supplies for the forces overseas or in disposing of surplus supplies after the Armistice was signed.

General McRoberts was graduated from Baker University, Baldwin, Kansas, in 1891. He holds degrees of A.B., A. M., and LL.D., from Baker; and LL.B. from the University of Michigan. He is on the Board of Directors of The American Sugar Refining Company, The Consolidated Coal Company, The American Ice Company, The National Surety Company, The Kansas City Southern Railway Company and other corporations. General McRoberts has been a Director of the Army Ordnance Association since its foundation, having been re-elected recently to serve until October, 1925.

General McRoberts

The following have accepted commissions in the Ordnance Officers' Reserve Corps since the last issue of ARMY ORDNANCE:

Colonel Bryant H. Blood, Lieut. Col. Charles E. Fuller, Majors Arthur Cobb, Clarence E. Coolidge, Parker V. P. Dodge, Harrison W. Hayward, Captains Bay E. Estes, John W. Hobbs, Henry Bryant, Raymond E. Kirk, Josiah P. Wilbar, Arthur F. Van Buskirk, 1st Lieutenants Charles A. Brace, Roy S. Haggard, Clarence B. Mills, Clarence F. MacKay, Arthur F. Schubert, George R. Seligman, Charles H. Towns, 2nd Lieutenants Howard C. Abbott, Levi Ballard, Lee R. Bradley, John F. Collins, Jr., Winthrop K. Coolidge, Arthur T. Hunter, Donald A. McArthur, Bruce M. Mossman, Edward F. Seiller, Charles M. Taylor, Jr., Carl E. Wahlstrom.

A reassignment of reserve officers assigned to Ordnance procurement districts has been completed. The object is to assign captains and lieutenants to their resident districts.

Brigadier General John Ross Delafield

The Secretary of War announced, October 26, 1923, the appointment of Colonel John Ross Delafield, Chief of the New York District Ordnance Office, to the rank of Brigadier-General, Ordnance Officers' Reserve Corps.

General Delafield was appointed Major, Ordnance Department, U. S. A., September 17, 1918, and assigned to duty in the Finance Section of the Office of the Chief of Finance. Later he was assigned to duty as financial manager of the Finance Division of the District Ordnance Office in Chicago. The financial operations of this office rank third in disbursements among the twelve Ordnance Districts.

On December 5, 1918, he was ordered to duty with the Chief of Ordnance in Washington to advise and guide the action of the different District Claims Boards in the adjustment and settlement of war contracts. He was promoted to the grade of Lieutenant Colonel, Ordnance Department, on March 25, 1910, and made a member of the Ordnance Claims Board.

He was promoted Colonel, Ordnance Department, on June 28, 1919, and made a member of the War Department Claims Board. He was Chairman of the Board of Contract Adjustment until his honorable discharge, July 1, 1920. General Delafield was awarded the Distinguished Service Medal with the following citation: "For exceptionally meritorious and distinguished service as chairman of the War Department Board of Contract Adjustment."

General Delafield

General Delafield was born on May 8, 1874, in New York City and is senior member of the legal firm, Delafield, Powell, Thorne and Rogers. He was appointed Colonel, Ordnance Section, Officers' Reserve Corps, February 21, 1921. General Delafield was elected president of the Reserve Officers' Association at the annual convention of that organization in Chicago, October 29, 1923.

Training courses for Reserve officers will be conducted at Rock Island Arsenal and Frankford Arsenal from November 12-24, 1923, inclusive. A report of these courses of instruction will be given in next issue of ARMY ORDNANCE.

In May, 1924, a course of training will be held at Rock Island Arsenal for captains and lieutenants of the Ordnance Reserve Corps assigned to the St. Louis, Chicago, Cincinnati, Cleveland and Detroit District Ordnance Offices.

Recent Patents

Brief Descriptions of Inventions of Interest to Ordnance Engineers

Compiled by W. N. Roach, Chief, Patent Section, Office of the Chief of Ordnance

PATENTS of recent date in which the readers of ARMY ORDNANCE may be interested include the following:

Artillery Materiel

Patent No. 1,454,950, issued to James M. Boyle, under the Act of March 3, 1883, for optical system, covers a range finder in which the object is made visible in stereoscopic or spherical stereoscopic relief. The device is of particular use in antiaircraft fire control.

Patent No. 1,455,771, issued to M. Anderson, for a process for expanding and smoothing the bores in gun barrels. The barrel is rough-bored, and if desired, reamed sufficiently to smooth the bore; it is then placed in a suitable support and a sphere of metal harder than the material of the gun and of the required diameter forced through the bore by pressure.

Patent No. 1,459,800, issued to E. Schneider, assignor to Schneider & Cie, for gun carriage having cranked axle-trees, discloses a gun carriage of this type with special improved means for moving the axle-tree from its lowermost to its highest position.

Patent No. 1,460,419, issued under the Act of March 3, 1883, to B. P. Joyce, for counterpoise, covers a novel counterpoise intended for use in counterbalancing a gun designed for high angles of fire.

Patent No. 1,460,420, issued under the Act of March 3, 1883, to B. P. Joyce, for counterpoise, discloses a counterpoise for counterbalancing a gun in which means are provided for varying the force exerted by the counterpoise to correspond with variations in the effective weight of the gun.

Patent No. 1,460,505, issued to E. Schneider, assignor to Schneider & Cie, for a wheeled gun carriage having divergible trails, shows a gun carriage of this type with definite means for negotiating the carriage and bringing the gun to a proper upright position.

Patent No. 1,461,561, issued to H. Romberg, assignor to the Rheinisch Metallwaaren und Maschinenfabrik, for a recoil gun discloses a gun in which the cradle and gun are mounted on an elevating mechanism, while the trunnions are on trails which extend to the rear.

Patent No. 1 462,280, issued under the Act of March 3, 1883, to Dayton A. Gurney, for a trail stop, covers a special form of trail stop connected between the trails and a bearing ring on the center pin.

Ammunition

Patent No. 1,453,717, issued to H. S. Miller for a time fuse, covers a time fuse of the powder-train type in which a constant and uniform pressure is maintained on the powder-train irrespective of the external atmospheric pressure.

Patent No. 1,453,718, issued to H. S. Miller for the process of controlling the burning of time powder trains describes a method for controlling the pressure in a fuse of the powder-train type.

Patent No. 1,455,741, issued to E. J. T. Wennerstron, assignor to Aktienolaget Bofors, for a fuse, in which the primer and detonator shells are normally remote with a special locking means for retaining them in firing position.

Patent No. 1,456,204, issued under the Act of March 3, 1883, to John H. Woodberry, for a base fuse, covers a fuse having a normally restrained, unarmed firing-pin; means for arming the pin; a movable detonator and primer carrier; and means for locking the carrier at the limit of its movement.

Patent No. 1,456,341, issued to W. O. Snelling, assignor to Trojan Powder Co., for an explosive composition, refers to a detonating explosive composition.

Patent No. 1,456,641, issued to O. D. Lucas, assignor to M. L. Experimental Ltd., for a shell fuse, discloses a fuse in which the piston or striker is acted upon by pressure of air during flight, no spring being used for keeping the striker away from the detonator.

Patent No. 1,454,414, issued to J. M. Skilling, assignor to E. I. du Pont de Nemours & Co., for a progressive nitrocellulose powder containing nitroguanidine.

Patent No. 1,455,354, issued to W. P. Porter for a projectile, discloses a projectile so formed as to prevent erosion in the gun.

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Books

Economics

"Practical Economics." By Henry P. Shearman, Professor of Economics, Miami University. McGraw-Hill Book Co., New York; viii plus 388 pages. Price, $2.50.

This is a well-written and very readable exposition of standard economic theory containing an ample amount of illustration drawn from modern business conditions.

Professor Pearson appears to have made a happy selection of material to be included in the text. He has devoted his space to those branches of economic theory bearing directly upon business practice, excluding such subjects as socialism, the theory of taxation, etc., which are interesting but have no direct bearing upon the field which the author has set out to cover.

It should be especially valuable to the active business man who has not the time to read the more elaborate standard works of Taussig, Marshall, etc.—R. H. S.

Military Transport

"Military Motor Transportation," prepared and published by the Coast Artillery School, Ft. Monroe, Va.

The present edition of Military Transportation is a revised edition of "Motor Transportation for Heavy (Coast) Artillery," published at the close of the war by the Coast Artillery School, Ft. Monroe, the original having been compiled by Captains E. S. Fraser and R. B. Jones, C. A.

Like the first issue, the present edition is largely a compilation of data covering the more important units of various types of vehicles in use by the Army during and since the war. Chapters on the principles governing the operation of internal combustion engines, carburetion and theory of electrical equipment make up a small though important part of the entire text. While written with the idea of applying to military vehicles, it gives the reader a good practical knowledge of automotive equipment, in general.

The particular value of the book in the military service is the indication, by its compilation, of increased interest in automotive equipment. A wider diffusion of knowledge is necessary if there is to be a successful application of automotive vehicles to military use. With the increased use of special vehicles, such as tanks, motor carriages, special tractors or trucks, the more thorough the understanding of basic principles of this equipment, the more certain of success in the operation of the equipment will be the forces equipped with it. Indications are that the automotive equipment will in some instances, at least, be highly specialized equipment and its proper maintenance will require a thorough training in the principles governing its operation.—G. S.

Armaments

"The Problem of Armaments." By Arthur Guy Enoch, M. Inst. Mech. E. The MacMillan Company, 1923. 196 pages. Price, $1.50.

Close to the end of this book the author says (page 169) "The problem of armaments is anything but academic." It is therefore somewhat disheartening to find a subject which the author expressly declares to be non-academic, and which has been considered so for ages by general consent, dscussed in a rather ethereal and impractical way.

"The Problem of Armaments," be it said, is a recent contribution to the literature on war prevention. With its aims and objects every reasonable man must be in sympathy. The author has compiled statistics on military and naval expenditures of the principal countries of the world, together with figures on the losses of life and property during the World War. Copious quotations are given from the addresses and writings of many statesmen during and since the war. In this respect the book is of excellent reference value.

But as its reference value enhances its logic recedes. Some idea of the scope of the work may be gained from a casual glance at the contents. There is a chapter on the natural man and the ordinary citizen and their reasons for maintaining armaments, which diagnoses the case as a vicious circle in which all Powers (so-called) race for military supremacy. Then follow facts and figures on the extent of the problem, and then arguments and opinions, and the book closes with an "indictment of civilization."

Drawn up in quasi-legal form, the indictment charges for the first count that the leaders of men have failed to learn wisdom—to which we, as defendant, plead "Guilty" and reply all the greater the need for armament. The second count charges that the lessons of history have been lost—to which the defendant pleads that on the self-same evidence the lessons of history unmistakably demand armaments. The last two counts charge that armaments have prostituted the brain and brawn of mankind—to which the defendant replies that if principle is to be sacrificed because the effort required to defend it is too great, or the danger too imminent, then "Judgment thou art fled to brutish beasts and men have lost their reason."

For an obviously sincere presentment of the case as he sees it the author is to be commended, but for a real solution of a time-worn problem the proposed remedy is of little moment.—L. A. C.

Waste in Industry

"Waste in Industry." By the Committee on the Elimination of Waste in Industry of the Federated American Engineering Societies. McGraw-Hill Book Company. 409 pages. $4.00.

This book has received the praise and sanction of the engineering profession of the country—attributes which it well merits.

Mr. Hoover, Secretary of Commerce, under whose auspices the work was compiled, has written a foreword that epitomizes the need and value of a survey of industry to determine its weak points. He says, in part, "We have probably the highest ingenuity and efficiency in the operation of our industries of any nation. Yet our industrial machine is far from perfect. The wastes of unemployment during depressions; from speculation and over-production in booms; from labor turn-over; from labor conflicts; from intermittent failure of transportation of supplies of fuel and power; from excessive seasonal operation; from lack of standardization; from loss in our process and materials—all combine to represent a huge deduction from the goods and services that we might all enjoy if we could do a better job of it."

We wish this book had been available in 1917-1918. Its finding then could have produced as much constructive practice as it undoubtedly will do in the ordinary affairs of peace-time manufacture.—J. F. M.

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